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ARE WE CLEANING UP?

10 SUPERFUND CASE STUDIES

A Special Report of
OTA's Assessment on
Superfund Implementation

CONGRESS OF THE UNITED STATES OFFICE OF TECHNOLOGY ASSESSMENT
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Foreword

In a few years, Superfund became part of the American vocabulary because so many people feel so strongly about toxic waste and cleanup of contaminated sites. They remain worried about environmental and health effects, but a new concern has come to the fore: the enormous amount of money and the long times to clean up an ever-growing list of Superfund sites. Yet, even while the public demands effective cleanups, nearly everyone speaking and writing about Superfund seems to feel that serious problems exist. And the focus of public attention has shifted from how much money ought to go to Superfund to how to achieve environmental results and efficiency. Right now there are more questions than answers about diagnosing and fixing Superfund.

Four committees of Congress asked the Office of Technology Assessment to assess how Superfund is being implemented under the 1986 Superfund Amendments and Reauthorization Act. They asked OTA to examine a number of technical issues that arise near the beginning of the complex Superfund process. The study was to assess the impacts of statutory provisions and program policies on environmental effectiveness and economic efficiency. The requesting committees were: the House Committee on Public Works and Transportation and its Investigation and Oversight Subcommittee; the House Energy and Commerce Committee and its Oversight and Investigations, and Transportation, Tourism, and Hazardous Materials Subcommittees; the Subcommittee on Superfund and Environmental Oversight of the Senate Environment and Public Works Committee; and the Subcommittee on Environment, Energy, and Natural Resources of the House Government Operations Committee.

During our Superfund Implementation assessment we realized that we could learn much by finding out how sites progress through the Superfund program and how—and when—critical decisions about their cleanup are being made. Before we could answer tough but general questions about making Superfund work better, we had to know more about what was actually going on. This special report presents 10 case studies of recent Superfund decisions at sites which OTA believes, from surveying over 100 recent cleanup decisions, to be representative of a broad range of contamination problems and cleanup technologies. We hope that everyone affected by Superfund can learn as much as we have from these case studies.

Many people have helped OTA with these case studies, especially Environmental Protection Agency staff around the country who provided us with primary information about the sites. Several companies that are responsible parties at sites also provided key documents. Responsibility for the contents of this document, of course, rests with OTA.

John H Gibbons

JOHN H. GIBBONS
Director

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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SUMMARY AND ANALYSIS

Introduction

Are we cleaning up the mess or messing up the cleanup? In the eighth year of Superfund, this central question is still being asked. These 10 case studies illustrate how the Environmental Protection Agency (EPA) is implementing the Superfund Amendments and Reauthorization Act (SARA) of 1986. OTA has examined a great many more sites and believes these case studies are representative of what is happening nationwide in the Superfund program.

This report examines two fundamental questions about using technology to clean up toxic waste sites. *First*, is the Superfund program consistently selecting permanently effective treatment technologies which, according to SARA, are preferable because they reduce "toxicity, mobility, or volume" of hazardous wastes? The answer OTA finds is that it is not.

Second, are land disposal and containment, both impermanent technologies, still being frequently used? The answer we find is yes. Future cleanups are likely for the wastes left in the ground or shipped to landfills.

The Superfund program promised a lot. People's expectations have been high, perhaps too high for such a new, complicated, large-scale effort. Frustration often makes it difficult to see real Superfund accomplishments. Since its inception at the end of 1980, Superfund has received a great deal of money, over $5 billion so far, to clean up the Nation's worst toxic waste sites. But OTA's research, analysis, and case studies support the view shared by most observers—including people in affected communities and people in industry paying for cleanups—that Superfund remains largely ineffective and inefficient. Technical evidence confirms that, all too frequently, Superfund is not working environmentally the way the law directs it to. This finding challenges all those concerned about human health and the environment to discover what is wrong and fix it. Whether Superfund will work cost-effectively over the long term depends on how cleanup technologies are evaluated, matched to cleanup goals, selected, and implemented and how permanent the cleanups will be. People want *their* cleanups—the ones they live near or pay for—to last. Improving public confidence in Superfund can be approached from different directions, including the one taken in this report: making better decisions about cleanup technology.

Too much flexibility and lack of central management control are working against an effective, efficient Superfund program. EPA Regions, contractor companies, and workers have substantial autonomy. In principle, flexibility can lead to benefits. But the case studies show the Superfund program as a loose assembly of disparate working parts; it is a system of divided responsibilities and dispersed operations. There is no assurance of consistently high quality studies, decisions, and field work or of active information transfer. The need for cleanups, the newness of the technological challenge, and the growth of Superfund mask the inexperience and mobility of the work force. Program managers have not offset inexperience in technical areas and management with tight management controls and intensive educational programs for government and contractor workers. Oversimplified "bean counting" of results instead of evaluations of what those results mean technically and what they accomplish environmentally provides too little incentive for quality work. The current decentralized system also does not assure higher levels of *program* efficiency over time, even though some workers and offices may become much more effective and efficient.

A widespread belief among Superfund workers is that "every site is unique." There is a kernel of truth to this belief. Yet uniqueness has been carried to an extreme and has blocked understanding of common site characteristics, common cleanup problems, common solutions, and common experiences with site studies and decisions. Identifying these commonalities is necessary to understanding how Superfund is being implemented nationally and understanding how to improve the program. At the beginning, when only a few cleanups were addressed, sites looked very different from each other. Now, with hundreds of cleanups examined, it is easier to see the commonalities and to benefit from the experiences to date. The case studies discuss similar experiences at various Superfund sites and help illustrate the link between identifying commonalities and achieving consistent cleanups.

Cleanup costs are major issues in the case studies. In site cleanup decisions, many people in government and industry want to keep costs as low as possible. Hence, there is a tradeoff between environmental protection goals (How clean is clean?) and the cost of the remedy selected (Is it cost-effective?). There is also a tradeoff between effective cleanup at *some* sites versus no action at others. These tradeoffs are getting more difficult as more and more sites requiring cleanup are identified. SARA's *preference* for permanently effective treatment technologies—not a requirement that they always be used—makes these tradeoffs even harder; it also places more importance on the accuracy of cost estimates and on evaluations of the permanency of different cleanup technologies. By understanding the capabilities of different cleanup technologies, it is easier to understand how compromises between cost and environmental performance can lead either to "gold plated" or "band-aid" cleanups.

The Importance of the Record of Decision

A crucial step in the complex process of moving a site from discovery to remediation (see box 1) is the ROD's *technology selection*.[1] Cleanup technology determines whether contamination will be eliminated or reduced to a safe level and environmental protection achieved, as well as determining cleanup cost. Technology selection is the primary focus of this OTA report. But the ROD decision is not everything. Just as a map is not the territory, a ROD is not the cleanup. Future analysis of the environmental results of cleanups is necessary to see how the ROD strategic plan is implemented. Because cleanups have been fully implemented at so few sites and the data are so sparse, this study does not fully examine actual cleanup effectiveness and consistency with ROD goals. But the case studies examine the entire history of the sites. And for some of the sites discussed here, the technologies selected have failed or early work to clean up immediate threats has made matters worse for final cleanup.

By examining RODs in detail, the functioning of Superfund comes into focus because everything that was done before the ROD must be considered and everything to come later must be anticipated. Analysis of RODs offers enormous educational value to improve Superfund implementation because they represent the critical junction between extensive studies and expensive remedial cleanups. Cleanup costs vary widely, from several hundred thousand dollars to tens of millions of dollars. To put cleanup costs in perspective, consider the simple concept of acreage. Data on 15 of the cleanups reviewed in this study indicate that total cleanup costs can reach $500,000 to $1 million per acre.

The Usefulness of Case Studies

In Superfund, case studies are particularly important because, even after 8 years, cleanup technology is a new and fast-changing field and the work force is relatively young and inexperienced. Recent college graduates are often put in charge of multimillion-dollar projects at EPA. These people have had no direct experience and no coursework on cleanup, and they have almost no one to learn from, as turnover is high. People in contractor firms also lack experience. Research papers and technical manuals have significant limitations too. They are quickly outdated, are

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[1] EPA has said "The Record of Decision . . . is the centerpiece of the administrative record against which the Agency's decisionmaking may be judged by the courts." [U.S. Environmental Protection Agency, "Interim Guidance on Superfund Selection of Remedy," Dec. 24, 1986.]

Box 1.—How Does Superfund Operate?

The Superfund system is complex. Sites are identified and enter an inventory because they may require a cleanup. At this point, or at any time, a site may receive a *Removal Action* because of emergency conditions that require fast action or because the site could get a lot worse before a remedial cleanup could be implemented. (Most of SARA's requirements for remedial cleanups do not apply to removal actions, even though removal actions can cost several million dollars and resemble a cleanup.) In the pre-remedial process, sites receive a *Preliminary Assessment* (PA); some then go forward to a *Site Inspection* (SI), with some of those sites scored by the *Hazard Ranking System* (HRS). If the score is high enough, the site is placed on the *National Priorities List* (NPL) and becomes eligible for a remedial cleanup paid for by the government, if necessary, or by responsible parties identified as having contributed to creating the uncontrolled toxic waste site. Under current procedures, only about 10 percent of sites which enter the system are likely to be placed on the NPL. Some States have their own lists of sites which require cleanup; these often contain sites not on the NPL.

NPL sites receive a *Remedial Investigation and Feasibility Study* (RIFS) to define contamination and environmental problems and to evaluate cleanup alternatives. The public is given an opportunity to comment on the RIFS and EPA's preferred cleanup alternative. Then, EPA issues a *Record of Decision* (ROD) which says what remedy the government has chosen and the reasons for doing so; the decision may be that no cleanup is necessary. A ROD may only deal with part of a site's cleanup and several RODs may be necessary for a site. The ROD also contains a summary of EPA's responses to public comments. EPA chooses the cleanup goals and technology in the ROD. In actual fact a number of actions involving different technologies are likely to be chosen for any but the simplest sites. The ROD is like a contract in which the government makes a commitment to actions which will render the site safe. If responsible parties agree to clean up the site, they sign a negotiated consent decree with the government; this stipulates the exact details of how the responsible parties will proceed. If the cleanup uses Superfund money, the State must agree to pay 10 percent of the cleanup cost.

In the post-ROD process, the site receives a *Remedial Design* (RD) study to provide details on how the chosen remedy will be engineered and constructed. The whole process ends with the *Remedial Action* (RA), the actual implementation of the selected remedy. Many cleanups include long-term monitoring to determine whether the cleanup is effective and if more cleanup is necessary. A ROD may be reopened and amended because of new information discovered or difficulties encountered during the design and remedial action. When a cleanup is deemed complete and effective, the site can be delisted by EPA from the NPL.

too theoretical, assume substantial technical knowledge, are either too detailed or too general, and may be biased to boot. Attending conferences where new cleanup technologies are discussed in detail is difficult because of heavy workloads and limited funds.[2] Moreover, helping to inform the public is also critical, especially because SARA increases the participation of communities in the program through technical assistance grants. These grants have not been available, however; EPA only began accepting applications in April 1988.

The case studies examine the decisionmaking *process*, the quality of the *information* used in it, and how well the decision and its technical support are *communicated* by EPA to the public. Unlike "bean counting" statistics, which give quantitative program results for a large number of sites, case studies show how the complex Superfund system really functions and illustrate the *quality* of its environmental performance. Case studies cannot totally describe the extensive site studies (the RIFSs) which precede the ROD. Nor can they go behind the scenes to investigate all the reasons for decisions. But the ROD and its supporting RIFS are intended to stand alone in making the government's case for the selected remedy and are the primary information sources in the 10 case studies.

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[2] For example, at EPA's annual research symposium in May 1988 dealing with treatment of hazardous waste only nine EPA staff people who may be implementing Superfund (i.e., not in the Office of Research and Development) were registered out of a total of over 700 people.

This report does not aim to prove whether a technology is good or bad, or whether a decision is unequivocally right or wrong. Cleaning up toxic waste sites is fraught with technical uncertainties and surprises which cannot be eliminated entirely. The issue of quality of RODs is not a black or white situation.[3] Each one will have good and bad points. Any cleanup technology can be used effectively for some applications, and every complex cleanup decision has strong and weak points. There is no problem finding important, correct statements in case study RODs. Indeed, this report often uses statements from one case study RIFS or ROD to illustrate inconsistency or to underscore a point about a problem in another ROD. Generally speaking, the decisions made in these 10 case studies are questionable because, for example:

- If different and readily available technical information had been used, the decision would have changed significantly.
- The range of cleanup alternatives was too narrow.
- The analysis was not comprehensive and was not fair to different technologies.
- The study work was not internally consistent.
- Mistakes were made in calculations and estimates.
- Critical assumptions were false.
- Conclusions were stated without analysis and documentation.

On a broader scale, other questions are important: Are government policies and EPA's organization getting in the way of solid, defensible technical work? Is the timing of key pieces of work, such as testing technologies, poor? Looking across sites, are there *trends* for problems in Superfund technology selection?

The last question is especially important. It is crucial not to look narrowly at single sites but across sites. This is key to central, national oversight of Superfund. While individual case studies can address technical soundness in a specific ROD, all of them together show how consistent the program is nationwide in understanding the advantages and disadvantages of cleanup technologies and in responding to the statutory requirements on cleanup technology selection. As does other information, RODs show that Superfund is being implemented in a highly decentralized manner. There is inconsistency in ROD format and presentation of information, examination of cleanup alternatives, and technology selections. In itself, this is not necessarily bad, but it does mean that central management oversight and controls by EPA are necessary to avoid inconsistency leading to confusion, unnecessary costs and, for some sites, ineffective cleanup. Lack of consistency among hundreds and, eventually, thousands of sites is not an academic issue. Harm to human health and the environment, loss of public confidence in government, and wasting money are what's at stake.

The following case studies also show how a site moves through the Superfund system. General perceptions about delays are documented. Rarely has so much information been assembled on individual sites, possible here because EPA has provided OTA with several databases. RODs do not contain such comprehensive information, which itself is an important observation. On the other hand, there are many areas of interest which are not covered in these case studies. Documents on a Superfund site can fill file drawers. There are many legal and procedural aspects of Superfund; these case studies focus on technical areas and issues. While legal and liability issues get enormous attention, environmental protection is the reason for

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[3] An experienced attorney advises responsible parties: "Legal issues, scientific and technical findings, plus the all-important policy component all affect EPA decisions. Nowhere is this more clearly shown than in the context of a Superfund Record of Decision . . . the statute calls on EPA to make decisions based on which remedy is cost effective or which 'adequately' protects public health. Applying these terms entails a degree of subjective judgment." [P.H. Haller, *Hazardous Materials*, January/February 1988.]

Superfund and ultimately it is technology which must get the cleanup job done.

Superfund's Better Side

A small fraction of RODs meet SARA's requirements. Six recent well-done RODs are briefly summarized below. While not perfect, each ROD sets a good remedial action plan, each selects what is likely to be a permanently effective treatment technology, and each provides adequate data and discussion to justify the technology choice. These six RODs contrast sharply with the 10 case studies which are the focus of this report.

Cooper Road Dump, Voorhees Township, New Jersey

EPA Region 2; NPL #473/770[4]—The ROD of 9/30/87 decided to take no further action at the site. A detailed technical case, based on substantial site sampling, supported the conclusion that previous removal actions at the site had left it permanently clean. The only question this ROD raises is why the site scored so high on the HRS and wound up on the NPL. In hindsight, Cooper Road Dump illustrates a "false positive," a site that went through the Superfund system unnecessarily. Indeed, in a survey of EPA Regional staff, this site was included on a list of "sites on NPL that should not be."[5] No significant Federal or State money was spent to prove that no cleanup was necessary; the responsible party paid for the work.

Davis Liquid Waste Site, Smithfield, Rhode Island

EPA Region 1; NPL #216/770; estimated cost, $28 million.—The ROD of 9/29/87 selected a comprehensive remedial action plan. The plan included: 1) onsite thermal destruction of 25,000 cubic yards of excavated raw waste and contaminated soil with greater than 2 parts per million (ppm) of volatile organic chemicals; 2) placement of incineration ash and pollution control residues that are found toxic through testing in an onsite RCRA hazardous waste landfill; 3) provision of alternative water for affected offsite residents; and 4) restoration of groundwater by onsite treatment using air stripping and carbon adsorption.

The supporting Feasibility Study (FS) was a textbook example of careful analysis, which included alternative technologies and citations of experiences at other cleanup sites. Most striking was the early elimination of nontreatment options, such as landfilling the hazardous waste, because, as stated in the FS, they "do not provide for any treatment of contamination." The analysis also reviewed costs for substantial pilot treatability studies during the post-ROD design phase (the RD) as well as acceptable cancer risk levels as cleanup goals. However, a 1 in 100,000 cancer risk level was used rather than the 1 in 1 million level more frequently used. Another, and probably related, reason why this ROD is not perfect is that some untreated hazardous material will be landfilled onsite instead of being treated. The higher risk level seems to have been a compromise made to reduce cleanup costs. Also, the delay of the treatability testing until after the ROD is undesirable; although for this site there was more information available to justify the technology selection than in some of the case studies.

The Davis remedial plan used an excellent interpretation of cost-effectiveness for making technology choices: "an alternative which has a similar public health and environmental benefit to other alternatives can be screened out due to costs that are higher in order(s)-of-magnitude."[6]

Love Canal, City of Niagara Falls, New York

EPA Region 2; NPL #142/770; estimated cost, about $30 million.—The ROD of 10/26/87 altered an earlier decision at Love Canal to use onsite land disposal for dioxin contaminated sewer and creek sediments. Now, a mobile thermal destruction unit will be used onsite to destroy and remove dioxin with an efficiency of 99.9999 percent. The cost for treatment will be twice that for land disposal, but the ROD selected thermal destruction on the basis of its ability to meet statutory requirements by eliminating toxicity and mobility. In addition, several site demonstrations elsewhere had successfully destroyed dioxin-contaminated soil with mobile thermal destruction units. EPA responded to extensive community comments against landfilling the contaminated material onsite and also decided not to attempt to separate materials with less than 1 part per billion dioxin (EPA's cutoff for acceptable contamination) because of uncertain reliability in doing so.

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[4] Ranking on National Priorities List and total number of ranked sites as of July 1987.

[5] U.S. Environmental Protection Agency, unreleased contractor report written by CH2MHill, November 1986.

[6] Compare this to EPA's guidance which lacks the concept of comparable environmental protection: "[cost-effectiveness] requires ensuring that the results of a particular alternative cannot be achieved by less costly methods. This implies that for any specific site there may be more than one cost-effective remedy, with each remedy varying in its environmental and public health results." [U.S. Environmental Protection Agency, "Interim Guidance on Superfund Selection of Remedy," Dec. 24, 1986.]

Operating Industries, Inc., Monterey Park, California

EPA Region 9; NPL #71/770; estimated cost: $4.8 million.—The ROD of 11/16/87 concerned an interim remedial action required to manage contaminated leachate at the site, which had a long, complex cleanup history. The ROD selected an onsite leachate treatment system with several proven technical steps that can reduce a diverse set of organic and inorganic contaminants to levels low enough to permit discharge to a local water treatment plant. The key steps will be gravity separation, coagulant addition, dissolved air flotation, filtration, air stripping with vapor phase carbon adsorption, and liquid phase granular activated carbon adsorption.

The analysis of alternatives was first rate. Two constraints were applied that ruled out more innovative approaches. First, the action had to be implemented easily and rapidly. Second, it had to be able to cope with major fluctuations in the composition of the leachate. Thus, some technologies that would actually destroy organic contaminants, such as plasma arc thermal destruction and wet air oxidation, both followed by stabilization of solid residues containing toxic metals, were not considered because they would probably face delays because of State regulatory requirements and possibly public concerns. The disadvantage of the selected remedy is that the technologies used rely almost entirely on separation. Therefore, significant amounts of concentrated hazardous residues will have to be moved offsite for disposal or treatment.

There was some laboratory testing of site leachate during the FS. Also, the process leading up to the ROD was rigorous, including an extended public comment period with an unusual opportunity for local citizens to review a draft ROD. (Normally, the public gets a very brief statement of EPA's preferred remedy to review.) Although there was keen community interest, little of it dealt with the selection of technology, but rather with the specific location on which the leachate treatment facility would be built.

Re-Solve, Inc., North Dartmouth, Massachusetts

EPA Region 1; NPL #206/770; estimated cost, $19.9 million.—The ROD issued on 9/24/87 is one of the most technically detailed and complete RODs reviewed for this study. A previous cleanup based on an earlier ROD was stopped when four additional hot spots of contamination were found. The newly selected remedy consisted of: 1) the source control phase of onsite treatment of 25,500 cubic yards of excavated PCB contaminated soils and sediments in a mobile dechlorination facility (volatile organic compounds will also be reduced); and 2) aquifer restoration by pumping, repeated flushing, and treatment involving air stripping and carbon adsorption, particularly for volatile organic compounds. The site will be evaluated every five years because some hazardous substances will remain there; curiously, there are no land use restrictions.

While dechlorination was considered an innovative technology, its selection was based on positive pilot test results on an actual Superfund site with similar contamination and climatic conditions.[7] (Other work by EPA shows the approach effective in getting residual levels of PCBs in soils down below 1 ppm.)[8] Additional pilot study results will be obtained onsite prior to use, and if dechlorination is unsuccessful, the ROD specified that onsite incineration will be used instead. Similar treatability and pilot tests will be performed for the groundwater cleanup phase prior to full-scale use.

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[7] The technology is sold by six vendors according to U.S. Environmental Protection Agency, "A Compendium of Technologies Used In The Treatment of Hazardous Wastes," September 1987.

Cleanup goals at Re-Solve were based on risk analysis on the basis of possible residential use of the site. A 1 in 100,000 excess (over background) cancer risk level was chosen for the soil and groundwater cleanup instead of the more common 1 in 1 million level. Accordingly, PCBs in the soil will be reduced to 25 ppm, which is a higher concentration than goals set at other sites.[9] For example, 20 ppm was chosen at the Ottari and Goss/Great Lakes Container Corp. site in New Hampshire; 5 ppm, at the Renora site in New Jersey; 1 ppm, at the Tacoma Tar Pits site in Washington; and 1 ppm, at the Liquid Disposal site in Michigan (where a 1 in 1 million risk was used). A recent EPA document refers to cleanup to "the desired background levels (1 to 5ppm) or less."[10] In addition, an assessment by EPA's Office of Health and Environmental Assessment concluded that a range from 1 to 6 ppm PCBs in soil is equivalent to 1 in 100,000 cancer risk.[11] The Re-Solve ROD, therefore, illustrates the compromise between level of cleanup and acceptance of cost by the government and responsible parties. The FS noted that "the volume of PCB contaminated soils increases exponentially as the cleanup levels become more protective." While the final decision may be disputed by some people, particularly on the issue of residual PCB level, the decisionmaking process is clear and there is public accountability.

Seymour Recycling Corp., Seymour, Indiana

EPA Region 5; NPL #57/770; estimated cost, $18 million.—The ROD issued on 9/30/87 was the second one for the site. The selected remedy has several key components: 1) a full-scale vapor extraction system to reduce the substantial presence of volatile organic compounds; 2) the extraction and treatment of contaminated groundwater at and beyond the site boundaries; 3) the application of nutrients to remaining contaminated soil to stimulate biodegradation; 4) the installation of a multimedia cap to restrict direct contact and limit water intrusion; 5) deed and access restrictions; and 6) a detailed monitoring program and technical criteria to detect failure and to plan future action if necessary.

A good technical analysis supported the selection of this remedy over alternatives such as incineration and in situ soil washing. Incineration would have cost $37 million and in situ soil washing would have cost $17 million, while the chosen plan will cost $18 million. But technical impediments—the large size of the site (14 acres), the large quantity of contaminated materials (about 100,000 cubic yards), and the dangers of excavating soil with large amounts of volatile compounds—not *cost*, were the reasons for rejecting alternatives that may have provided more substantial treatment and detoxification. In addition, the groundwater treatment is estimated to take from 28 to 42 years, but there is no faster alternative available. Of some concern is that treatability studies were not done before the ROD. But the extraction technology is well proven and the final Seymour implementation plan is well thought out.

Summary of Trends From 10 Case Studies

As a rule, RODs are fraught with problems. The 10 case studies, chosen out of over 100 RODs reviewed, illustrate in concrete ways some disturbing trends among these problems —trends that compromise the ultimate protection of human health and the environment (see box 2 for capsule findings). These trends are summarized below.

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[8] A. Kornel et al., "Field Experience With the KPEG Reagent," paper presented at EPA's *Fourteenth Annual Research Symposium*," May 1988.

[9] The PCB concentration level corresponding to the 1 in 100,000 risk level is 30 ppm, but EPA decided that the uncertainty of the approach allowed them to use 25 ppm as being representative of that risk level. The PCB level for the 1 in 1 million risk level was 3 ppm. Also, it was estimated that onsite groundwater may contain 10 to 15 ppb PCB after cleanup, which is far in excess of 0.08 ppb, the health-based cleanup level for a 1 in 100,000 cancer risk for PCBs.

[10] U.S. Environmental Protection Agency, "Report on Decontamination of PCB-Bearing Sediments," January 1988.

[11] As reported by EPA in its ROD for the Liquid Disposal site in Michigan, Sept. 30, 1987.

Evaluation and Selection of Permanent Treatment Technologies

Many good, permanently effective waste treatment technologies are on the market but, too often, are not fully examined, or are not selected for use. A ROD may simply opt not to treat a site at all but rather to bury waste in a landfill or to cap the hazardous area, both impermanent options. A site's having too little or too much contaminated material is often cited as a reason for not choosing a permanent treatment technology. Too little material and too much material both mean high cost for treatment relative to costs for nontreatment alternatives, but cost alone should not guide decisions.

Describing a cleanup technology as a "treatment" can be misleading. SARA sees a treatment as a technology "that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume" of hazardous materials "to the maximum extent practicable," but SARA's "treatment" allows much interpretation. Furthermore, EPA has not established a hierarchy of preferred results and types of treatment.

Not all treatments accomplish the same things. For example, thermal destruction and some biological and chemical treatment can irreversibly destroy or detoxify nearly all of *some* toxic substances and therefore reduce their mobility and volume. But a number of physical and chemical treatments can separate organic and inorganic materials and release the hazardous material collected and concentrated to the environment (e.g., air stripping) or place it in a landfill (e.g., carbon adsorption, precipitation, soil washing, solvent extraction). The preferred use of separation technology uses treatment to destroy the hazardous material collected.

Chemical fixation, stabilization, and solidification treatments usually only reduce mobility, particularly for toxic metals, (but usually increase volume) and they nearly always leave some uncertainty about long-term effectiveness because laboratory tests can neither fully duplicate field conditions over long periods nor establish what actually is happening to the contaminants.[12] EPA has said that "There is, at present, no set protocol for evaluating the efficacy of stabilization technologies."[13] The use of stabilization technologies for high levels of organic contamination is particularly unproven.[14] A recent EPA review of stabilization technology said:

> Although S/S [solidification/stabilization] technologies have been used for more than 20 years, there exists little information on long-term physical durability and chemical stability of the S/S mass when placed in the ground . . . . Generally, S/S technology is recognized effective for inorganic waste, while organic wastes have the potential to cause problems . . . . The long term effects of organics on S/S performance are important, however, little research has been performed. . . . the capability of the technology to perform satisfactorily over long periods of time has yet to be determined . . . . uncontrolled air emissions are a potential problem to workers and the environment.[15]

These EPA views are inconsistent with current EPA decisions that choose stabilization and call them permanent remedies.

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[12] The attractiveness of stabilization type technologies is oftened expressed in noncost terms, such as: "Long term effectiveness of incineration, stabilization, and solidification are comparable." [ARCO Petroleum Products Co., "Critique of Sand Springs Operable Unit Feasibility Study," Aug. 31, 1987.)

[13] L. Weitzman, L.E. Hamel, and E. Barth, "Evaluation of Solidification/Stabilization As A Best Demonstrated Available Technology," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.

[14] For example, a recent EPA study found "large losses of organics during the mixing process" [L. Weitzman et al., op. cit.]. Another EPA study showed that stabilization was not competitive with thermal and chemical treatment technologies and soil washing for organic contamination [R.C. Thurnau and M.P. Esposito, "TCLP As A Measure of Treatment Effectiveness: Results of TCLP Work Completed on Different Treatment Technologies for CERCLA Soils," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988]. A demonstration of a stabilization technology under EPA auspices concluded that "for the organics, the leachate concentrations were approximately equal for the treated and untreated soils" [P.R. de Percin and S. Sawyer, "SITE Demonstration of Hazcon Solidification/Stabilization Process," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988].

[15] C.C. Wiles and H.K. Howard, "U.S. EPA Research in Solidification/Stabilization of Waste Material," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.

Box 2.—10 Case Study Sites With Capsule Findings

Case Study 1
Chemical Control Corp., Elizabeth, New Jersey
EPA Region 2; NPL rank: 223 out of 770
Estimated cost: $7.4 million

Unproven solidification (chemical fixation) technology was selected to treat in situ highly contaminated subsurface soil, which previous removal actions had left below the water table and covered up with gravel. No treatability study was used. The cost of incineration was overestimated. The cleanup will leave untreated contamination onsite.

Case Study 2
Compass Industries, Tulsa County, Oklahoma
EPA Region 6; NPL rank: 483/770
Estimated cost: $12 million

Capping (containment) of waste was chosen over incineration. Capping was called a cost-effective, permanent cleanup even though it does not provide permanent protection comparable to incineration. No commitment was made to treat contaminated groundwater.

Case Study 3
Conservation Chemical Co., Kansas City, Missouri
EPA Region 7; NPL rank pending
Estimated cost: $21 million

Capping of the site and a hydraulic containment system to pump and treat some contaminated groundwater were chosen over excavating and treating contaminated soil and buried wastes, which was recommended in an EPA study and by the State. Water treatment cannot remove all the diverse contaminants at the site. The ROD said that no estimate could be made for the duration of the cleanup.

Case Study 4
Crystal City Airport, Crystal City, Texas
EPA Region 6; NPL #639/770
Estimated cost: $1.6 million

Excavation of contaminated soils and wastes (which were buried in a previous removal action) and their disposal in an unlined landfill with a cap over it were selected over incineration. No treatability study supported the conclusion that the selected remedy is permanent on the basis of the adsorption of diverse contaminants to site soil. Major failure modes for the landfill were not examined.

Case Study 5
Industrial Excess Landfill, Uniontown, Ohio
EPA Region 5; NPL #164/770
Estimated cost: $2 million

Providing alternate water to houses that have or are likely to have contaminated wells was a satisfactory interim remedial action. However, actions to address the source of contamination and to stop and treat contaminated groundwater are long overdue.

Case Study 6
Pristine, Inc., Reading, Ohio
EPA Region 5; NPL #531/770
Estimated cost: $22 million

In situ vitrification was developed originally for radioactive soils, but its use for chemically contaminated sites is still unproven. In situ vitrification was selected—without treatability test results—chiefly because its estimated cost was about half that of onsite incineration. But the estimated cost for incineration is probably high by a factor of 2. Incineration offers more certainty and probably would cost no more than the chosen remedy. Groundwater will be pumped and treated by air stripping and carbon adsorption.

Case Study 7
Renora, Inc., Edison Township, New Jersey
EPA Region 2; NPL #378/770
Estimated cost: $1.4 million

The selected remedy makes use of offsite landfilling for soils contaminated with PCBs. Also, biological treatment was selected for soils contaminated with diverse organic compounds and toxic metals and for contaminated groundwater, but no treatability study supported its selection.

Case Study 8
Sand Springs Petrochemical Complex
Tulsa County, Oklahoma
EPA Region 6; NPL #761/770
Estimated cost: $45 million

EPA originally said that solidification technology was ineffective for the high organic content wastes and that onsite incineration was effective. EPA then reversed itself and selected solidification for most of the cleanup, which the responsible party had claimed effective based on its treatability study. Incineration is to be used if solidification technology is not successfully demonstrated or fails after solidified material is landfilled on the floodplain site, but criteria for failure are unspecified.

Case Study 9
Schmalz Dump Site, Harrison, Wisconsin
EPA Region 5; NPL #190/770
Estimated cost: $800,000

A simple compacted earth cover over the soil contaminated with lead and chromium was selected. Solidification/stabilization treatment was rejected, although this was a textbook example of appropriate use of the technology. Voluntary well abandonment and monitoring was chosen over pumping and treating contaminated groundwater.

Case Study 10
Tacoma Tar Pits, Tacoma, Washington
EPA Region 10; NPL #347/770
Estimated cost: $3.4 million

No treatability study results supported the selection of chemical stabilization. Significant amounts of untreated contaminants as well as the treated materials will be left onsite. The effectiveness of the treatment is uncertain. Incineration was said to offer no better protection and was rejected because of its higher cost.

Moreover, a cleanup may consist of many different operations in which treatment may be only a small part. Removal actions may send hazardous waste to landfills, perhaps much more than may be treated subsequently. Or action may be taken on contaminated soil but not on contaminated groundwater or vice versa. Too many RODs assume that *any* use of *any* technology is a treatment that meets the letter and spirit of the statutory requirement. General Superfund statistics on treatment can be misleading because they do not distinguish among different technologies used at a site for different amounts of material.

There is no clear line between sufficient and insufficient technical and economic data for selecting among cleanup technologies. A ROD may choose an unproven or inappropriate technology or both with the claim that it is a permanent remedy, or a ROD may eliminate a technology because it remains untried on a large scale. It is not uncommon to have a multimillion-dollar cleanup decision made without **any** technical data to support it, either from the technical literature or from tests done on site material.

Information used to compare treatment technologies is often inaccurate and incomplete. Poor information compromises the RIFS, the selection of remedy, and public support of certain remedies. Alternative treatment technologies that are practical are sometimes ignored or not chosen. Costs for innovative technologies may be unreliable, either too low or too high. Good or bad experiences at other sites are not studied. An example is the failure, discovered in 1985, of chemical stabilization treatment at the Conservation Chemical Co. site after only a few years of use; nevertheless, RODs are selecting chemical stabilization for similar problems more than ever before.

Contractors may quote a wide range for direct costs per unit of material treated for any given treatment technology. For example, quoted unit costs of onsite incineration ranged from a low of $186 per cubic yard for Seymour Recycling to $730 per cubic yard at Pristine for the same amount of treated material; both sites are in the same EPA Region. The unit cost quoted for mobile, onsite incineration in the Chemical Control case in New Jersey and at the Pristine case in Ohio (where the technology was rejected) was twice the unit cost used at the Davis Liquid Waste site in Massachusetts (where the technology was selected). At the Chemical Control site, both $500 and $750 per cubic yard unit costs were quoted for two cleanup alternatives using the same onsite incineration. In both cases, the material burned was essentially the same and the type of incineration technology was the same (the difference in the options was where the residuals were disposed).

Such variations make it hard to establish a technology's cost-effectiveness—or lack of it—relative to other technologies. Even when a contractor uses the same burden rate (see below) among ROD cleanup alternatives, inaccurate unit costs can distort the comparative analysis. For example, with Pristine, if direct cost had been $186 per cubic yard instead of $730 (with the same 83 percent burden), the total cost for incineration would have been $15 million, not $51 million; Pristine had rejected incineration and selected in situ vitrification for $22 million. If total estimated costs have any effect on post-ROD activities, then actual cleanup costs for clients—and profits to contractors—may vary substantially and some may be much greater than they could be.

Contractors estimate cleanup costs by adding to direct costs substantially different levels of indirect cost (burden or markup). In the Pristine case, the burden—various contingencies, construction services, and design costs—amounted to 83 percent of direct costs, while for Davis and Re-Solve, involving the same RIFS contractor, the burden was 35 percent; the Davis and Re-Solve indirect costs explicitly included pilot study work, while the costs for Pristine did not. For Seymour Recycling, the burden was 60 percent; for Chemical Control, 56 percent; and for Crystal City, 29 percent. The range in burden rates over different sites and across and within contractors illustrates an important management problem in Superfund.

RODs cannot always depend on the results of tests done for other sites. Treatability studies refer to tests on site material and are supposed to bridge the gap between general information about the technology and the more specific information needed for technology selection in the ROD. Results of treatability studies on one site, particularly for innovative technologies, do not necessarily mean that a given treatment will work or not work for some other waste site, unless the conditions are nearly identical or the technology's performance is not waste specific. The problem is that some technologies are very waste specific, and it is impossible to accurately extrapolate positive test results from one waste to another, especially because Superfund sites often have very complex, site-specifc wastes. Incineration of organic contaminants is nonspecific, whereas biological treatment is quite waste specific. Onsite treatment technologies (in which the waste is brought to the technology) perform more predictably than in situ technologies (in which the technology is brought to the waste) because the latter's effectiveness depends on site conditions, such as chemical, physical, and biological properties of the soil. These can vary widely from site to site.

When they are done, most treatability studies are not done early enough. It is critical that they be done during the RIFS *before* the ROD, but most are done during the design phase *after* the ROD. Treatability studies will improve the RIFS by providing technical data to support the ROD's analysis of cleanup alternatives and to ensure that the ROD's cleanup choice is effective and satisfies statutory requirements. However, EPA now often speeds up RODs, apparently to meet fiscal year goals; thus treatability tests during the RIFS are sacrificed. This sacrifice can backfire. Negative test results after the ROD would indicate the wrong technology choice and the waste of a lot of time and money. Worse, altering a ROD at this point, even for good reasons, may meet some resistance. Finally, when responsible parties or technology companies conduct these tests, EPA may need to assure their objectivity by independently verifying the results.

Some RODs choose technologies that are in EPA's Superfund Innovative Technology Evaluation (SITE) program, an indication that a technology has not yet been proven. For example, the Chemical Control ROD chose a new type of in situ stabilization, the Pristine ROD chose in situ vitrification, and the Sand Springs ROD chose a stabilization technique in the SITE program. If, as EPA says, the SITE program exists to obtain "sound engineering and cost data" and to "resolve issues standing in the way of actual full-scale application," then how can such ROD selections be justified? If they are justifiable, are the SITE demonstrations really necessary?

The chemical character and complexity of site contaminants and how they affect the use of some technologies do not get enough attention. A few indicator compounds, used to represent all site contaminants for risk assessment, may be inappropriate for technology evaluation because physical and chemical properties may differ from the way health effects vary. The result can be a poor technology choice. Also, site sampling may be insufficient to detect hot spots of contamination that would facilitate using limited treatment to cut cleanup costs. In addition, groundwater monitoring may not be reliable.

Impermanent Technologies

When wastes are left in the ground or in groundwater or are redisposed in a landfill, a ROD may claim that the remedy is permanent when, in fact, it is not. Permanence may be claimed even when technical factors suggest a high probability of failure, that is, of release of hazardous substances, and of another cleanup. In such cases, the ROD would be more credible if it acknowledged the remedy as impermanent and defended it on its own merits relative to truly permanent alternatives. Moreover, an impermanent remedy and a false sense of security could lead, for example, to land use that would only complicate future cleanup and pose unacceptable risks.

Contrary to the law, containment/land disposal decisions seldom analyze the risk of future failure, damages, and further cleanup. While some RODs claim that containment/land disposal techniques are proven and reliable technologies with no implementation problems, there is evidence to the contrary. For example, the RCRA clay cap being installed at the Winthrop Landfill Superfund site in Maine failed in September 1987 before its construction was completed. The ROD of November 1985 said the technology was proven, routinely used, and posed no construction difficulties. There had been no analysis of potential failure; under the original Superfund statute—the Comprehensive Emergency Response and Liability Act of 1980—such analysis was not required. Under SARA it now is.

Sometimes a ROD does not commit to a definite outcome even though it appears to have selected a technology. Contingencies, uncertainties, and multiple future options do not assure the public that there will be a permanent remedy and that it will be fully implemented in a timely and effective way. Often, the ROD does not provide specific technical criteria for subsequent decisions, such as for groundwater cleanup or land use, nor are there necessarily assurances of independent validation of data and effective EPA oversight of activities by responsible parties and contractors. Specific groundwater monitoring requirements are particularly important because recent EPA research has found that "low sampling frequency coupled with the generally smaller sampling networks suggest that efforts to characterize groundwater contamination at [Superfund] sites may be inadequate."[16]

Impermanent remedies, which provide less protection than permanent ones and do not assuredly meet cleanup goals, are often selected purely because they are cheaper in the short run; in the long run they are very likely to be more expensive. Regarding cost-effectiveness, when two or more cleanup options offer the same level of environmental protection and can meet established cleanup goals (from risk assessment or existing regulatory standards), everyone will agree that the lowest cost option should be chosen. Impermanent technologies are not cost-effective remedies and do not satisfy SARA, therefore, when permanent technologies are practical. The average estimated cost of the cleanups in the six good RODs noted earlier was $20 million. In contrast, the average estimated cost of not-so-good cleanups in the 10 case studies below was $12 million. (In the 10 case studies, the average for the five treatment remedies is $16 million and the average for the nontreatment remedies is $7.5 million.) It is true that a permanent cleanup based on treatment technology is likely to require a larger initial outlay than an impermanent cleanup based on land disposal. Even a modest cost difference can mean a lot added up over thousands of sites.

EPA is less responsive to community concerns about a remedy being impermanent than to interests which favor a lower cost impermanent remedy. Thus community concerns about impermanence are not very likely to lead to a more expensive cleanup technology. There are many incentives for various parties to keep cleanup costs low by using onsite containment/land disposal or even some relatively inexpensive forms of treatment, such as stabilization and separation technologies. These parties include potentially responsible parties (PRPs) that may have to pay for the cleanup, States that have to provide 10 percent of the cost (unless PRPs pay), and EPA which wants to distribute available funds as broadly as possible and which wants to obtain settlement agreements with PRPs to reduce calls on Superfund money.

In selecting cheap, impermanent remedies, claims of comparable estimated costs may hide the truth that low cost was the key deciding factor. Getting accurate costs to compare cleanup alternatives is crucial. Overestimates or underestimates may be used to justify a choice or a rejection. For example, at the Conservation Chemical Co. site in Missouri, where a settlement with PRPs was involved, an EPA contractor and the State recommended one remedy (rejected) which was said to cost $24 million over another remedy (selected) which cost $21 million. But available EPA data suggest that the rejected remedy would actually cost from $40 million to $150 million.

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[16] R.H. Plumb, Jr., "A Comparison of Ground Water Monitoring Date From CERCLA and RCRA Sites," *Ground Water Monitoring Research*, fall 1987, pp. 94-100.

Program Efficiency

EPA pushes most RODs to completion by the end of the fiscal year and this kind of bureaucratic pressure can lead to poor cleanup decisions. To meet deadlines, EPA may deemphasize public comments that would otherwise lead to reevaluation of facts and technologies; EPA may make a hasty, technically unsupported decision as it did at the Sand Springs site in Oklahoma. Typically, there is less than one month between the end of the public comment period and the issuance of the ROD. (See table 1 for summary data from the 10 case studies on times to reach certain stages in the cleanup process.) The RIFS may also suffer from hurried review by EPA because of pressure to issue a ROD by the end of the fiscal year or quarter.

The pre-remedial process has received little attention even though sites can be releasing hazardous substances into the environment and, during the time they are unexamined and unattended, get worse. The time from site identification through placement on the NPL is about 3 years for the case studies (and often much longer for other sites examined by OTA).

The time between a site's placement on the NPL and the start of the RIFS varies greatly, averaging about 16 months. Nationwide, there is no apparent relationship to the site's HRS score; a high score does not necessarily speed cleanup (e.g., three sites with similar high HRS scores waited 39, 15, and 3 months). For sites within an EPA Region, however, the HRS score does seem to matter; this time the waiting period decreased with decreasing score or hazard level (e.g., in Region 6, the HRS score/time to RIFS start were 47/39, 32/12, and 29/-3).[17] That is, the more hazardous the site according to the HRS, the longer it takes to start the RIFS on the site. This seems opposite to what might be desirable; but in Region 6, the French Limited site ROD said that "The position (rank) of a site on the [National Priorities] list is inconsequential."

The RIFS process, from start of the studies through issuance of the ROD, takes from 2 to 3 years. Within this time, early decisions to eliminate some technology alternatives and perform treatability studies for others could be, but usually are not, made. Studying more technologies than necessary increases the time and cost of the RIFS, makes it more difficult to decide to do treatability testing on the most viable tech-

Table 1.—Times for Sites To Reach Points in the Superfund Process[a]

	Average	Range
From entry into Superfund inventory until:		
Preliminary Assessment completion	18 months	1-45
Site Inspection completion	21 months	1-44
Placement on National Priorities List	36 months	4-75
Start of RIFS	44 months	20-68
Completion of RIFS	75 months	47-103
Signing of ROD	81 months	50-104
Completion of ROD remedy (ESTIMATED)	10 years	6-20
Between Preliminary Assessment completion until:		
Site Inspection	14 months	0-39
Placement on NPL	32 months	3-73
Start of RIFS	42 months	13-68
Between placement on NPL and start of RIFS	16 months	−3-39
Duration of RIFS:		
Studies	32 months	21-38
Total period (studies through ROD)	34 months	24-39
Between signing of ROD and ROD estimate of completion of remedial action	38 months	20-120
Duration of public comment period	33 days	24-44
Time between end of public comment period and signing of ROD	34 days	15-122

[a]Based on the 10 case studies in this OTA special report

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[17] The last score/time is an example of a site for which the RIFS was started 3 months *prior* to the site's placement on the NPL.

nologies and sometimes contributes to poor RODs.

After the ROD, actual cleanup action, including remedial design, takes 2 to 3 years. Sometimes there are repeated RODs and new actions on different parts of the cleanup (called operable units) and sometimes on the same part of the cleanup.

The entire process from site identification through final (estimated) remedial cleanup can frequently take about 10 years. Unexpected findings sometimes complicate the process. For example, remedial cleanup stopped at the Conservation Chemical site in Missouri and at the Re-Solve site in Massachusetts when new information about the sites' contamination showed a need for more studies, another ROD, and new cleanup strategies. Some risks to health and environment are likely during such long regrouping periods. Contaminants are likely to migrate from areas of high to low concentration, increasing the extent and complexity of cleanup, particularly for groundwater.

Risk Management and Cleanup Goals

There are often problems with how risks are assessed and how cleanup goals are met. Different levels of risk may be used and very different cleanup technologies may be said to be comparable, because EPA allows a broad range from 1 in 10,000 to 1 in 10 million excess lifetime cancer risk.[18] Sometimes compromises are made to reduce cleanup cost by allowing a higher risk than the 1 in 1 million cancer risk commonly used in Superfund. A cleanup can be deemed complete even though significant contamination remains onsite or migrates offsite. Regarding cleanup goals, a cleanup technology can be justified in superficial ways. Hazards (the source of the risk) may not be eliminated through permanent technologies but exposures to the hazard—i.e., the risk—may be reduced through impermanent actions, such as capping a site, or institutional controls, such as deed restrictions that have uncertain future implementation.

RODs do not consider cumulative exposures and risks from multiple sources of similar hazardous substances. Cleanup levels may look acceptable on a site basis but might not when two or more Superfund sites are close together. An example is the two Superfund sites in Oklahoma on opposite sides of the Arkansas River; neither ROD evaluates risks from the other site. Environmental risks seem to take a back seat to bureaucratic definitions of Superfund sites and to constraints imposed by seeking funds from responsible parties.

The risks of transporting hazardous materials offsite for land disposal or even treatment are not considered. Furthermore, SARA's requirements to use permanent treatment technologies are not applied by EPA to waste sent offsite. The ROD can say that the cleanup will be permanent, even though the site was originally a land disposal facility, and the wastes are slated for a landfill that itself might become a Superfund site. Moving hazardous waste from one hole in the ground to another is the nonsolution that was behind SARA's preference for permanent cleanup. For the purpose of many Superfund cleanups, EPA's assumption seems to be that hazardous waste sent to a regulated landfill will never fail and require cleanup even though there is widespread agreement, even within EPA, that landfill technology will ultimately fail. There are also many widely recognized uncertainties about regulatory compliance and future corrective action.

Most RODs seem uncertain about or do not address future land and water use in judging whether a selected remedy will be safe and permanent. In some cases, there is a lot of interest in reusing the land for productive purposes. For example, at the Schmalz site in Wisconsin, where contaminated soil is to remain in place, the ROD makes no land use restrictions. Any remedy that leaves hazardous waste in place or caps it suggests the need for explicit attention to future land and perhaps groundwater use.

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[18] Cancer risk assessment is not the only way cleanup goals are established. Current regulatory standards for acceptable levels of contaminants are also used, but these are not available for many contaminants. When risk assessment is used, probable, worst case, or other levels of risk are calculated. Sometimes precleanup risks are also calculated.

The Record of Decision Document

The technical content and quality of RODs varies substantially across and within EPA Regions. Supporting RIFSs generally lack citations to the technical literature, important data, and discussions of actual experiences, good and bad, at sites that have used the technologies under consideration. Multimillion-dollar decisions are often made without any significant technical data to support them. A ROD may drop or choose a cleanup technology with little or no discussion or justification.

Probable causes for the meager level of technical detail are: enormous public pressure to clean up sites sooner; attempts to compensate for delays; bureaucratic pressures to produce RODs faster; poor contractor performance; lack of central, national oversight; and some attempts to carry out activities after the ROD when there is less public scrutiny. Conflicts of interest also may be a problem. Does the RIFS contractor own a cleanup technology or will it or some affiliated company stand to profit if a particular cleanup technology is selected? Is the RIFS contractor also a responsible party at the site? Does a responsible party own the cleanup technology selected for the cleanup?

EPA Regions are not using a standard format for RODs. Lack of uniformity makes RODs difficult to analyze and compare for oversight and quality control purposes. Of particular importance is the way alternative cleanups are evaluated. Different criteria are used.[19] Sometimes the evaluation focuses on each alternative separately with very little comparison. When comparative analysis is used, it often is superficial and qualitative or semi-quantitative with only rankings for alternatives.

Even for a technical expert, the basis for a cleanup decision is often hard to understand; the public has an even greater problem. RODs often lack much key information, such as test data, other nearby sources of contamination, earlier actions, or even an earlier ROD. In hindsight, earlier actions are frequently ineffective from a longer term perspective and often make subsequent attempts to permanently clean sites more costly and difficult. At the Crystal City site in Texas, for example, a previous action buried hazardous materials which must now be excavated and re-buried onsite in a final cleanup. The ROD offers an opportunity—not yet used—to evaluate past site actions and to learn from them.

Sometimes a remedy and its implementation constitute a research or demonstration project because there is no treatability study data or the technology isn't proven for the site. But the cleanup is not publicly presented as experimental or highly uncertain. While the technology selected may, in some cases, make sense, the public may ultimately think it unfair of the government to hide the uncertainty and risk. Moreover, making the claim that a permanent remedy has been selected is questionable if the technology is experimental.

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[19] A July 1987 directive from EPA's Assistant Administrator for Solid Waste and Emergency Response outlined nine "key criteria which should be considered in evaluating and comparing alternatives." An earlier directive contained essentially the same evaluation criteria, although they were not presented as clearly. [U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, directives 9355.0-21 (July 24, 1987) and 9355.0-19 (Dec. 24, 1986)].

10 CASE STUDIES

Introduction

Each of the 10 case studies in this report is drawn from a Record of Decision (ROD), which is EPA's official understanding of the facts from site studies and EPA's explanation of how the facts support its selection of a cleanup technology. Each ROD also includes a summary of how EPA responded to public comment and generally includes a summary of the administrative record (related documents) for the site. EPA can and sometimes does reject, change, and supplement the findings of the contractor(s) who prepare the RIFS and draft the ROD.

Methodology

These 10 case studies were selected from recent RODs, from September 1987 through December 1987, which EPA has acknowledged came under SARA. OTA identified issues in its 1985 study *Superfund Strategy* and in the ongoing Superfund Implementation study of which the case studies is just one part. This other work helped in the selection of representative case studies. The 10 cases here were chosen to illustrate different technology selection problems, none of which are unique to these sites, and to illustrate different types of sites and hazards. This report discusses about 10 percent of all recent RODs to which EPA has applied SARA. OTA examined nearly all recent RODs—over a hundred—to verify that the case study sites are representative.

Format for Case Studies

The case studies are presented in a standard format. Following is a sample of the format with explanations, where necessary, of the categories and of the terms and sources used in the case studies. **Unless noted otherwise, the quotations in the case studies are from the site's ROD.** Statements from other RODs, from other case studies, and other Superfund sites are often used in the case studies to illustrate program inconsistencies. To complete each site's history, two EPA data management systems were needed: 1) the CERCLIS inventory of all sites reported to EPA, and 2) the Superfund Comprehensive Accomplishments Plan (SCAP). The latter is a budget management system; OTA used data from SCAP NPL Site Summary reports dated October 27, 1987.

Sample Format

Name, location of site, and EPA region:

Capsule OTA findings:

Key dates:

Entered Superfund system: EPA maintains an inventory of sites called CERCLIS. The date when the region gets notification of a site is recorded is the site discovery date. Many sites new to Superfund come with long histories of contamination and cleanup efforts.

Preliminary Assessment: The Preliminary Assessment is the first screening step in the pre-remedial process; it consists mostly of examination of existing records. It is done by EPA contractors or by States. Sometimes a PA is done after other actions which are supposed to come before it, apparently to satisfy the requirement that it be done.

Site Inspection: The Site Inspection involves some field work and testing to define the nature and scope of the hazard. The SI is the second screening step in the pre-remedial process and leads to Hazard Ranking System (HRS) scoring of the site. The SI is done by EPA contractors or States; the initial scoring is by EPA contractors, EPA regional staff, or States.

National Priorities List
- *proposed date:*
- *final date:*
- *site rank:*

Sites that get an HRS score of 28.5 or more go on the NPL and become eligible for remedial cleanup. Initially EPA proposes a site for the NPL, and, after an opportunity for public comment, the site can become a final NPL site. Final sites are ranked by their HRS score; the ranks in the case studies are from the NPL as of July 1987. Then the NPL had 770 ranked sites and more than 200 proposed sites. EPA revises the NPL only periodically, approximately once a year. The significance of the rankings for taking action has not been made clear by EPA. A site can receive various Superfund actions without being on the NPL.

RIFS start and completion: The Remedial Investigation/Feasibility Study (RIFS) provides the information base for the ROD. RIFSs are done by private engineering consulting firms, paid by EPA, responsible parties, or States.

Public comment period before ROD: EPA is required to make available certain documents for public review for 21 days prior to the ROD; the period can be extended.

Signing of ROD: EPA Regional Administrators officially sign RODs, although in a few cases the EPA Headquarters Assistant Administrator, Office of Solid Waste and Emergency Response, may do so.

Estimated complete remediation: The ROD normally estimates when the final action or, if the action is not final, when the whole cleanup will be done.

Total time: The total elapsed time of above dates.

Brief description of site:

Major contamination/environmental threat:

HRS scores: EPA's policy is that a site score a minimum of 28.5 to be placed on the NPL. (Once only, States can nominate one site for the NPL regardless of its score.) The maximum subscores for groundwater, surface water, and air are 100, and a formula is used to combine the subscores so that the maximum total score is also 100. (This calculation applies to the version of the HRS used for the case study sites; a newer HRS version, required by SARA, may change this methodology.) There are many concerns about the accuracy of HRS scores and their use in ranking NPL sites; an HRS score may not paint an accurate picture of a site's original or current environmental threat. Sites are not rescored after removal actions or interim remedial measures.

Removal actions: Removals are site actions on non-NPL sites and on NPL sites before (or during) a remedial cleanup. They are usually handled by a different office within the Superfund program than that which handles the remedial cleanup. A variety of removal actions can be taken as emergency or time-critical measures. SARA authorizes more time and money for removal actions than did CERCLA.

Cleanup remedy selected:

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The Superfund Amendments and Reauthorization Act of 1986 (SARA) states that EPA shall: 1) "select a remedial action that . . . utilizes permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable," and, 2) if this is not done, "publish an explanation as to why a remedial action involving such reductions [in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant] was not selected." (SARA Section 121)

2) Accurate assessment of land disposal and containment alternatives.—SARA states that EPA shall "take into account:" . . . the long-term uncertainties associated with land disposal; . . . short- and long-term potential for adverse health effects from human exposure; . . . the potential for future remedial action costs if the alternative remedial action in question were to fail . . . " (SARA Section 121)

RIFS contractor: Information on time, cost, and company is normally available from the ROD; if not, OTA obtained it from other EPA sources.

State concurrence: Only information reported by EPA in the ROD was used.

Community acceptance: The ROD's responsiveness summary was chiefly used. It does not necessarily reflect the full range of public opinion about a site because it only describes direct interactions through the official public comment process between the community and EPA.

Special comments:

General conclusions:

Case Study 1
Chemical Control Corp., Elizabeth, NJ; EPA Region 2

Capsule OTA findings.—Unproven solidification (chemical fixation) technology was selected to treat in situ highly contaminated subsurface soil, which previous removal actions had left below the water table and covered up with gravel. No treatability study was used. The cost of incineration was over estimated. The cleanup will leave untreated contamination on the site.

Key dates:

- Entered Superfund system: 5/1/79
- Preliminary Assessment: 5/1/79
- Site Inspection: 4/1/79 - 8/1/82
- National Priorities List
  - —proposed date: 10/1/81
  - —final date: 9/1/83
  - —site rank: #223 out of 770
- RIFS start and completion: 12/31/84 - 6/30/87 (ROD says it began in 11/86, but SCAP has earlier date)
- Public comment period before Record of Decision: 7/6/87 - 8/14/87
- Signing of ROD: 9/23/87
- Estimated complete remediation: 28 to 32 months after ROD (around 4/90)

Total time.—11 years

Brief description of site.—"The site consists of this 2.2-acre property and the portion of the Elizabeth River adjacent to the property. . . . the water table aquifer at the site [is] saline and tidally influenced. The site is flat and barely above sea level. Chemical Control Corp. operated from 1970 until 1978 hauling, treating, and disposing of a wide variety of industrial wastes. Throughout its operations, it was cited for violations that included discharging liquids onto the ground adjacent to the Elizabeth River and accumulating thousands of drums of incompatible wastes."

Major contamination/environmental threat.—" . . . soils beneath those removed by the NJDEP [New Jersey Department of Environmental Protection] are highly contaminated with a variety of organic compounds and to a lesser degree with metals. . . . these contaminants are strongly adsorbed to the soil and are present in the groundwater in relatively low concentrations. The contaminants found in the [river] sediments . . . are not all attributed to the Chemical Control site." The contaminated layer "averages approximately ten feet thick. . . . some of the more mobile chemicals continue to leach into the groundwater. Significant health threats are posed by direct contact, fugitive dust emission, and volatilization. Contaminants are only leaving the site via the groundwater. . . . direct contact with sediments as well as ingestion of contaminated shellfish are both potential exposure routes. Flooding happens occasionally at the site now . . . " The ROD indicated a volume of contaminated material of 18,000 cubic yards.

HRS scores.—groundwater 0; surface water 18.18; air 79.49; total 47.13

Removal actions.—State removal of large quantities of wastes began in March 1979 and was interrupted by a major fire in April 1980. After the fire, the State removed more material, including 3 feet of surface soil which was replaced with gravel. Also, from November 1980 until July 1981, the State operated a groundwater recovery and treatment system. This action plus groundwater movement and not just the adsorption of contaminants to soil may explain why the subsequent Remedial Investigation found little contamination and why the HRS groundwater score in 1982 was zero. Overall, the State of New Jersey has spent $25 million on the site.

After the site became a Superfund site, four additional initial remedial measures were carried out (in 1984, 1985, 1986, and 1987) to remove more materials from the site.

Cleanup remedy selected.—Other than containment, treatment alternatives considered were soil washing, solvent extraction, and incineration. The selected remedy was in situ fixation (chemical fixation, stabilization, and solidification often are used to describe similar treatments). Fixation chemicals would be injected though an expandable bit drill which would pass through the gravel layer: "A series of overlapping columns would be formed converting all of the contaminated soil at the site into a solid mass. This would inhibit water from flowing through the site, thereby preventing the production of leachate. In addition, some contaminants may be chemically altered and incorporated in the solid matrix formed by this action, reducing the toxicity as well as the mobility of the contaminants. The potential for exposing the contaminated soil would be eliminated. [The treatment] will create a solid matrix that will have extremely low permeability. . . . because it is implemented primarily below ground, [the treatment] offers protection against releases during a flood."

The estimated cost for the selected remedy is $7.4 million, while the cost for excavation, onsite treatment, and onsite disposal of residues is $14.5 million for fixation and soil washing and $22.3 million for incineration. The ROD also commits to some other relatively minor removal actions and environmental monitoring, "including an evaluation after five years to assess its protectiveness to public health and the environment."

Satisfaction of SARA statutory requirements.

1) Selection of permanent cleanup.—"The remedial alternative presented in this document is a permanent solution for closure of the Chemical Control site. . . . this remedy satisfies the preference for treatment that reduces toxicity, mobility, or volume as a principal element. . . . this remedy utilizes permanent solutions and alternate treatment technologies to the maximum extent practicable. Based on the input received during the public comment period, this alternative has been selected by the EPA and the NJDEP as the final permanent solution for the site. [The selected remedy] also utilizes an alternative treatment technology that offers a more cost-effective remedy."

The fact that the ROD met SARA's requirement for a five-year review indicates that EPA recognizes that the selected remedy would leave untreated, undestroyed, and toxic wastes onsite. EPA normally responds to the statutory requirement for review for land disposal/containment remedies and when only partial destruction treatment technologies are used at a site. The review has implications for future land use because use of the land might interfere with reviews and because results of reviews might reveal hazards that would block land use.

A major issue with the selected remedy of in situ fixation is that it is not a proven technology; no data exist to show effectiveness for cleanup of a hazardous waste site comparable to Chemical Control. No treatability study was conducted prior to the ROD to provide evidence of effectiveness in terms of resistance to long-term leaching or actual toxicity reduction. The diverse set of contaminants at the site would pose a challenge to conventional chemical fixation techniques. The use of *in situ* fixation beneath the water table in saline conditions may exacerbate the difficulty of achieving an effective cleanup. Various ROD statements on this issue include:

- "Although in-situ fixation is not yet a standard construction practice, several vendors are available that provide this service."
- " . . . the in-situ process described in this document is currently being studied for use at other hazardous waste sites."
- "The long-term reliability of this alternative is especially *promising*" (emphasis added).
- "A treatability study and field test will be required during design to prove the technology . . . "
- " . . . environmental samples will be collected to monitor the effectiveness of the remedy." (No specific technical criteria are given.)
- "Although such an application of this technology is fairly new, promising results have been obtained in laboratory tests, and it is being tested at other hazardous waste sites and evaluated under the Superfund Innovative Technology Evaluation program. The Chemical Control project will benefit from the experience gained at these sites."

Despite the last comment, OTA has been only able to identify the evaluation within the SITE program. A vendor in conjunction with General Electric has demonstrated its technology at a GE site in Hialeah, Florida, in April 1988. PCB contaminated soil was treated. A demonstration report is supposed to be available approximately four to six months after the demonstration. OTA contacted the vendor of the in situ chemical fixation technology for the GE site and was told that no tests have been conducted on materials from Chemical Control but preliminary laboratory tests have been successful on material from the Hialeah site. GE will be using the technology to actually clean up the Hialeah site; the cleanup will constitute the SITE demonstration. GE plans to do this cleanup even though EPA has not officially sanctioned its use at Hialeah; the agency has problems in issuing regulatory permits for an innovative treatment technology, necessary because the cleanup is not at a Superfund site. Given the timing of the Hialeah demonstration, it is difficult to understand how the selected remedy can be already judged to satisfy requirements for Chemical Control. Officially, there are no performance criteria to prove the effectiveness of the technology. Moreover, one of the objectives for the SITE demonstration is to determine the "integrity of the solidified soil over a period of five years." (U.S. Environmental Protection Agency, "Superfund Innovative Technology Evaluation (SITE) Program," HWERL Symposium, May 9-11, 1988.)

But when will the technology be completely evaluated? Some innovative technologies have been demonstrated several times and still have uncertainties for broad use. The information available on the SITE demonstration is inconsistent with the schedule for implementation of the selected remedy given in the Chemical Control ROD and seasonal constraints may also delay cleanup.

Moreover, the SITE demonstration will not be performed on a comparable contaminated material. The presence of volatile organics and metals, for example, makes the Chemical Control project significantly different. A positive SITE demonstration result will not, therefore, substitute for a treatability study on Chemical Control material nor should it justify performing a pilot study at Chemical Control.

The EPA decision to use incineration at the Southern Crop Services site in Florida at about the same time of the Chemical Control decision undercuts the use of stabilization for Chemical Control. In justifying its selection of incineration, EPA said: "Solidification and fixation of pesticide contaminated soil was found to be technically unacceptable due to the high detected concentrations and because organic pesticides tend to leach from solidified material. This technology was deemed unacceptable." (U.S. Environmental Protection Agency, Region 4, memorandum, Sept. 8, 1987.) Pesticides are among the many different types of organic contaminants present at Chemical Control. The FS for the Re-Solve site in Massachusetts rejected stabilization because "there has been limited success in chemically fixing organic contaminants such as solvents and PCBs."

The ROD for the Liquid Disposal site in Michigan, which also selected stabilization for soil contaminated with organic chemicals, said that the hazardous substances "will not be permanently destroyed" and "hazardous chemicals still remain in that [treated] mass." And the FS for the site said: "Considerable research data exists demonstrating the effectiveness of this technology in immobilizing a wide range of contaminants, primarily inorganics. A substantial amount of data does not exist, however, to accurately judge the long-term reliability of the process." Of particular significance to the use of stabilization at Chemical Control, the Liquid Disposal ROD also selected a slurry wall and impermeable cap around and over the treated material, in part because it is necessary to "*protect the solidified soil/waste from degradation by upgradient ground water that is slightly contaminated with chemicals*" (emphasis added).

A recent EPA study found "large losses of organics during the [stabilization] mixing process." (L. Weitzman et al., "Evaluation of Solidification/Stabilization As A Best Demonstrated Available Technology," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.) Another EPA study showed that stabilization was not competitive with thermal and chemical treatment technologies and soil washing for organic contamination. (R.C. Thurnau and M.P. Esposito, "TCLP As A Measure of Treatment Effectiveness: Results of TCLP Work Completed on Different Treatment Technologies for CERCLA Soils," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.) A demonstration of a stabilization technology under EPA auspices concluded that "for the organics, the leachate concentrations were approximately equal for the treated and untreated soils." (P.R. de Percin and S. Sawyer, "SITE Demonstration of Hazcon Solidification/Stabilization Process," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.)

Senior EPA people have made an important observation about in situ stabilization: " . . . the decision to use a stabilization technique should be made only after the chemical and physical properties of the solidified waste have been extensively tested to insure that the required properties have been developed." (D.E. Sanning and R.F. Lewis, "U.S. EPA Research on In-Situ Treatment Technology," *Anatomy of Superfund*, proceedings of the 8th National Ground Water Quality Symposium, September 1986.) The ROD for Chemical Control does not meet these requirements.

An educational short course and two recent EPA documents on cleanup technologies make no reference to the selected technology. (U.S. Environmental Protection Agency, "Remedial Engineering of Hazardous Waste Sites," The National Hazardous Materials Training Center, October 1987; "A Compendium of Technologies Used in the Treatment of Hazardous Waste," September 1987; "RCRA/CERCLA Treatment Alternatives for Hazardous Wastes," October 1987.) The latter EPA document is used to teach people implementing hazardous waste programs about waste treatment and says: "Solidification technologies are designed to be used for final waste treatment. This means the technology should be applied only after other treatment techniques have been applied, i.e., incineration, chemical treatment or other."

Another observer has commented on this approach: "Experimental studies have been conducted in the field. The level of treatment achievable is variable, depending on the waste and soil conditions. The potential for long-term immobilization is unknown at this time. The reliability of the treatment is unknown since there is no information on its long-term effectiveness." (R. Sims et al., "Contaminated Surface Soils In-Place Treatment Techniques," Noyes Publishers, 1986.)

The Feasibility Study for the Crystal City site rejected in situ chemical stabilization: "Immobilization, chemical treatment, and physical treatments have not been shown to be feasible for in situ treatment of these contaminants as it is not possible to get a good, uniform, well distributed treatment." The focused FS for the Conservation Chemical Co. site in Missouri rejected in situ stabilization: "Technology [was] attempted and [was] found not feasible at other similar sites. Technology is not sufficiently developed." An addendum study also rejected in situ immobilization (which cannot be differentiated from stabilization): "Technology would not effect organic and other non-metallic contamination; thus, these substances would continue to be a source of contamination. Immobilization reactions are reversible." The FS for the Pristine site in Ohio rejected in situ chemical detoxification: "Treatability study is required to assure effectiveness. It is difficult to ensure proper reactant mixing and verify effectiveness."

The same contractor that prepared the Chemical Control FS has tested in situ chemical stabilization elsewhere. ("Feasibility Study Saltville Waste Disposal Site, Smyth County, Virginia," August 1986.) Successful laboratory and pilot tests led to the field testing of a particular in situ treatment; however, the field tests failed and the approach was dropped. This twist illustrates the uncertainty of a technology, even after successful laboratory tests.

The ROD said that the selected remedy "offers a level of long-term protection comparable to or exceeding that of any of the other alternatives." However, if the selected remedy has not been shown to destroy the organic contaminants the way incineration could, is this assertion of *comparable* permanence correct? Incineration followed by chemical fixation of the residue to immobilize toxic metals offers a higher level of protection. Therefore, the additional estimated cost for the incineration option (three times more than fixation) does not eliminate its cost-effectiveness. Also, the cost estimate for the selected remedy is unreliable because the technology has not been used before on such a site.

This ROD illustrated the benefit of examining the supporting Feasibility Study. In this case, the FS introduced several new elements:

1. The ROD did not reveal several facts about the site and the selected remedy that *were* in the FS: a) the curing time for the fixation material is about one month; b) there is a volumetric increase in the waste after treatment that depends on site materials and conditions; c) "It is unlikely that solidification can be effected in contaminated areas at the interface between the river and the site. This residual contamination will continue to flush from such areas surrounding the solidified mass"; d) "This alternative will not reduce any potential human health or environmental impacts associated with the contamination detected in the gravel cover atop the site"; e) " . . . even under nonflood conditions, the water table is quite close to the surface of the site"; and f) The estimated costs for the bench test and pilot test for the in situ fixation alternative are $770,000.

2. The FS analysis of the selected remedy suggested that there is reliable information on which to base conclusions. The text contained phrases such as: "has been demonstrated," "the available literature," and "it is reported," suggesting that technical literature and EPA reports were used. But, all the information came from a single vendor (identified in figure 3-6 in the FS). The FS also referred to the GE Hialeah site as a Superfund site, which it is not, and the FS said (in June 1987) that "a field application of the emerging technology is presently underway," which it was not.

3. The FS analysis of incineration is poor. The unit cost for incineration only (with other costs figured separately) was $750 per cubic yard for the combination of onsite incineration and offsite disposal (where a baseline of 21,000 cubic yards of soil was used) and $500 per cubic yard for the combination of onsite incineration and onsite disposal (where a baseline of 27,000 cubic yards of soil was used). These differences in unit cost and soil volume do not make sense. Other vendors are now quoting less than $300 per cubic yard for the volume of work at this site and, indeed, $300 per cubic yard was quoted in the FS for the Davis Liquid Waste site in Rhode Island (where onsite incineration was selected) and $186 per cubic yard was quoted in the FS for the Seymour Recycling site. The Chemical Control FS also stated that "Rotary kiln and fluidized bed incinerators are the only types of mobile units currently available." This statement is not true. According to EPA, there are three other types of full-scale mobile thermal technologies available: circulating bed, infrared, and wet air. (U.S. Environmental Protection Agency, "RCRA/CERCLA Treatment Alternatives for Hazardous Wastes," October 1987.) If $300 per cubic yard were used (with other costs factored in separately) for onsite mobile incineration of 18,000 cubic yards (the same amount of material as for the selected remedy), then the cost would be about $14 million. This cost compares to the ROD cost for onsite incineration with onsite disposal for 27,000 cubic yards at $22 million. The ROD omitted FS low and high cost estimates for the options. Since there is no field experience with in situ fixation, its high cost estimate of $14 million is significant as an estimate. Thus it is possible that incineration at $14 million might be about the same cost as the selected remedy and not three times more. More recently, after the ROD, a news story reported that the cleanup project's estimated cost is $10 million, with $750,000 allocated for the one-year design job, an amount which could not account for the cost of the treatability study. (*Superfund*, Feb. 1, 1988.)

4. The analytical framework used to evaluate alternative cleanup approaches is inconsistent with commonly accepted practice and with EPA's recommendations. A July 1987 EPA directive clearly recommended the use of nine criteria; an earlier directive was less clear. Only four criteria were used in this FS: technical fea-

sibility, public health and environmental concerns, institutional considerations, and cost. However, analysis using additional criteria, particularly factors such as reliability and implementability which are normally stressed, would have worked against the selected remedy. (Indeed, this analytical result happened in the ROD for the Conservation Chemical Co. site in Missouri, in which the only soil treatment alternative faired poorly on reliability and implementability and thus was rejected.) The Chemical Control ROD evaluated each cleanup alternative separately. An explicit comparison of alternatives weighing relative advantages and disadvantages was not done in the FS or the ROD. (At Conservation Chemical, the ROD comparative analysis of cleanup alternatives was done within individual discussions of evaluation criteria, a very useful approach compared to discussing each alternative for all criteria.)

To sum up, an analysis of the FS shows that there was little basis to select the in situ chemical fixation alternative and that the FS analysis was biased in favor of the selected remedy and against using onsite incineration. Onsite incineration is a proven, more cost-effective, and more reliable cleanup alternative than the FS and ROD indicated.

2) Accurate assessment of land disposal and containment alternatives.—To a significant extent, the selected remedy *is* a land disposal/containment approach because, unless shown otherwise with positive test results, chemical fixation cannot be assumed to detoxify all contaminants. Leaving the contaminated soil onsite and beneath the water table raises questions about future failure. No technical criteria were established to determine failure of the selected remedy. Failure is a real possibility, since the same generic treatment failed at the Conservation Chemical Co. site. A volume increase in the treated waste with the addition of fixation chemicals raises questions about the integrity of the resulting solidified mass within the site with in situ use. Costs were not estimated to repair a failure of the selected remedy.

A traditional containment wall was examined, but the ROD said that a containment wall might need replacement in the future. But the ROD noted that a wall "would offer effective protection if institutional controls were imposed to prohibit any future digging at the site."

Interestingly, in the Chemical Control situation, a containment approach might have made sense—as an interim measure—because there are many other sources of river contamination around the site that could reduce the effectiveness of a remedy that leaves site material vulnerable to recontamination. The ROD noted the risk of recontaminating clean material backfilled into the site. Contaminants from the river might also affect the effectiveness of chemical stabilization.

RIFS contractor.—State-led; NUS Corp. under subcontract to Ebasco Services, Inc.; about $1 million obligated. SCAP indicated a RIFS from 9/28/83 - 2/15/85 at a cost of $208,000, a subsequent ROD on 2/15/85, a Remedial Design at $504,000, and a Remedial Action at $485,000. There was no information in the 1987 ROD's site history on the earlier RIFS, ROD, and remedial action, and SCAP listed separately the interim remedial measures and removal actions with their costs. To confuse things still more, a master EPA list of all Superfund RODs showed an earlier ROD on 9/19/83.

State concurrence.—New Jersey agreed with the selected remedy.

Community acceptance.—The ROD said: "The main concern of local officials is that a thorough, permanent remedy be expeditiously implemented." The responsiveness summary also indicated some public concern about the effectiveness of the selected remedy, particularly because of its inattention to toxic metals.

Special comments.—The ROD did not address the problem of highly contaminated river residues. The chief reason is the other sources of contamination: " . . . remediation of the river sediments is premature." If the river residues are considered part of the Chemical Control site, then this ROD does not offer a final permanent cleanup of the entire site.

Why did the State leave the contaminated soil in place in a previous site action and cover it up with permeable gravel? This action complicates a permanent remedy and will contribute to continued leaching of contaminants into the river and its sediments for about 10 years. Even though EPA said that the contaminants adhere to the soil, not *all* the contaminants could behave so ideally nor, as discussed in the FS, will all contaminants be treated to reduce their mobility. The ROD gave no data to support the contention that all the contaminants are tightly bound to the soil. The ROD noted: "The NJDEP has also indicated that contaminant concentrations in the soil at Chemical Control exceed State guidelines." It is not clear why an interim containment action at the site, such as a slurry wall and cap, was not implemented years ago.

Other innovative in situ treatment technologies—including biological treatment and vitrification—could have been considered in treatability studies as viable candidates, but were not. The FS rejected in situ vitrification (ISV) on grounds that also could have been used to reject the selected remedy. Yet ISV was selected for the Pristine site, and the Crystal City FS evaluated ISV favorably, although it did not select ISV or any treatment alternative: "[ISV] has been successfully demonstrated in laboratory and bench testing. [ISV] was determined to be feasible given the existing information available and is retained for further evaluation." A recent NJDEP report's discussion on innovative/alternative technologies said: "Various technologies presently exist which can adequately address contaminated soil and other contaminated media. For example, waste vitrification (imbedding waste in glass) can immobilize organic or inorganic contaminants while generating residuals that are delistable and environmentally safe." Moreover, the NJDEP report also noted that treatability studies are done during the RIFS to "fill data gaps . . . and supply information needed to select a design alternative." (New Jersey Department of Environmental Protection, "Comprehensive Management Plan 1988-1992," October 1987.) The point here is not whether ISV is the best cleanup technology for the site but that a case could have been made to *evaluate* it as the ROD did for in situ stabilization.

The ROD had no summary of the administrative record which, because of the inconsistent information on dates, would have been very useful.

General conclusions.—EPA's high confidence and certainty about the selected remedy is unsupported by analysis. In this case as in several other case studies, the ROD did not follow EPA's guidance that ROD analysis "must be based on a specific process within [a] technology category . . . to ground the analysis in hard data." (U.S. Environmental Protection Agency, "Interim Guidance on Superfund Selection of Remedy," Dec. 24, 1986.) The ROD package contained a letter of August 31, 1987, in which EPA told the City of Elizabeth's Director of Health, Welfare and Housing: ". . . we feel that in-situ fixation will protect public health and the environment from any hazards posed by the site." As with the statements in the ROD about the selection being permanent, the statement in the letter was inconsistent with the need to prove the effectiveness of the remedy, through a treatability study, after it was selected but before it is fully applied. In the same letter to the city official, EPA said: "In the event that these tests show that in-situ fixation would fail to offer protection of public health and the environment, the ROD would be amended as necessary." Examining alternatives, selecting another remedy, amending the ROD, and implementing another remedy would, of course, take considerable time. Indeed, this scenario has happened at other Superfund sites, including the Re-Solve site in Massachusetts, the Conservation Chemical Co. site in Missouri, and at Love Canal in New York.

A systematic bias against incineration was suggested in the site FS evaluation, particularly for cost. Use of mobile incineration might not cost significantly more than the selected remedy, but it would offer more certain effectiveness.

The Chemical Control site illustrates the problem of delaying a treatability study until the design phase. While chemical fixation is considered a treatment, it cannot be assumed to detoxify all contaminants. A treatability study during the design phase should be limited to obtaining data necessary for the detailed, engineering design of the selected technology and also to develop technical criteria to guide potential bidders on the project. If a treatability study is necessary to show effectiveness, as in this case, then it should be done, as it sometimes is, during the RIFS process. If it is delayed, then "Such a deferral may result in a premature (and administratively 'irreversible') commitment to a technology that may not be appropriate for a given site." (D. Truitt and J. Caldwell, "Evaluation of Innovative Waste Treatment Technologies," *Waste Management Conference-Focus on the West*, Colorado State University, June 1987.)

The selected remedy for Chemical Control can be considered a land disposal/containment approach. OTA does not mean to challenge the merits of the in situ chemical fixation technology but does question the decisionmaking process used at this site. Making the remedy selection before treatability test results are available may mean that EPA was in a hurry to promote innovative treatment technology and to issue the ROD.

The ROD also did not assure a permanent remedy for the site because it ignored the cleanup of the highly contaminated river sediments, ignored the contamination in the gravel, and ignored the untreated material at the river's edge. The ROD over estimated the cost of onsite incineration, which could achieve more permanent, more complete, and more certain cleanup at a cost of about $14 million, instead of the ROD's $22 million estimate.

The serious complication of other nearby sources of contamination shows that Superfund sites cannot be seen in isolation. The ROD noted that recontamination of the site is a potential problem. Therefore, a case could have been made for coordinating this cleanup with others to assure an overall, permanently effective solution for all of them.

There seems to be an unusual interest in the RIFS and ROD process in reusing the site and constructing something on it, despite the uncertainty of the selected cleanup, despite the contaminated materials to remain onsite, and despite the other nearby sources of contamination. The FS indicated that the State of New Jersey owns the land and that, with the selected remedy, New Jersey's own law regarding real estate transfer would be violated if the site was put into commercial reuse "Since some residual contamination will exist in the gravel cover under [the selected remedy], and since the subsurface contamination will still be present (although immobile), it is unlikely that this alternative will comply with the concentration requirements of ECRA [New Jersey's Environmental Cleanup Responsibility Act]. It is felt that this alternative will be consistent with the intent of ECRA, however." The FS noted a cancer risk above 1 in 1 million for contact with the contaminated gravel, a risk that has implications for future use of the site and onsite workers.

Case Study 2
Compass Industries, Tulsa County, Oklahoma; EPA Region 6

Capsule OTA findings.—Capping (containment) of waste was chosen over incineration. Capping was called a cost-effective, permanent cleanup even though it does not provide permanent protection comparable to incineration. Treatment of contaminated groundwater is not yet planned.

Key dates:

- Entered Superfund system: 10/1/80
- Preliminary Assessment: 4/1/80
- Site Inspection: 7/1/82
- National Priorities List
  - —proposed date: 9/83
  - —final date: 9/84
  - —site rank: #483 out of 770
- RIFS start and completion: 6/29/84 - 7/13/87
- Public comment period before Record of Decision: 7/22/87 - 8/31/87
- Signing of ROD: 9/29/87
- Estimated complete remediation: 9/90

Total time.—10 years

Brief description of site.—The site is " . . . an abandoned landfill located west of Tulsa, Oklahoma. The site occupies an abandoned limestone quarry. From 1972 to 1976 the site was permitted and operated as a solid and industrial waste landfill. Physically, the site is situated on a bluff approximately one-quarter mile south and 200 feet above the Arkansas River. An elementary school lies within one-half mile and a major regional park is immediately adjacent to the site."

Major contamination/environmental threat.—" . . . a large number of organic and inorganic priority pollutants were detected. They include a total of 12 inorganic priority pollutants and at least 33 organic priority pollutants . . . pathways of possible off-site contaminant migration are surface water, groundwater, and air. The possibility also exists for direct contact at the site with contaminated source materials, such as sludge, soil, or sediments. The majority of the contamination in the groundwater is confined to the upper aquifer. Samples of groundwater from monitoring wells on the site are highly contaminated. This indicates a degradation of groundwater quality due to waste disposal in both the perched and deep aquifers. The volume of waste was determined to be approximately 620,000 cubic yards. The average groundwater flow rate of both aquifers is 720 gallons per day or an estimated 263,000 gallons of water per year [into Arkansas river]. The most recent fire burned for several years before it apparently burned out in 1984. . . . there exists a potential for future fires. . . . [During fires] elevated levels of air contaminants may present a health hazard."

HRS scores.—groundwater 11.05; surface water 18.46; air 59.49; total 36.57

Removal actions.—None indicated.

Cleanup remedy selected.—Two major alternatives were considered: 1) leaving waste in the ground, capping the site, and treating groundwater; and 2) incineration of excavated wastes. There are three parts to the selected remedy: 1) capping the site; 2) if deemed necessary through compliance, monitoring after installation of the cover material, collecting and treating onsite the contaminated groundwater in the upper, perched water bearing zone; and 3) installing fences and signs along the perimeter of the cap. "This alternative consists of site grading, cap placement, diversion of surface water, and air emissions monitoring. The site cap will be required to meet RCRA specifications. Groundwater will be treated at a later date *if found to be necessary*. The site will be monitored for a period of at least 30 years . . . to ensure that no significant contaminant concentrations migrate from the site" (emphasis added).

Estimated cost: $12 million.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The ROD said that " . . . [the selected] remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable." The ROD acknowledged that capping only reduces the mobility of contaminants; groundwater treatment would also "reduce the volume and toxicity of wastes on site to some degree." Hazardous residues from water treatment would be shipped offsite to a landfill.

Full onsite thermal destruction was examined as an alternative and was given highest ratings "because this process would destroy the organic compounds in the waste." Partial onsite thermal destruction of 2 percent of the waste, coupled with capping and groundwater treatment, would have been an improvement over capping and groundwater treatment alone. Regarding full onsite thermal destruction: " . . . this remedy is not cost-effective ($339 million vs. $12 million)." However, the ROD acknowledged that full incineration would give the best overall environmental protection. Regarding partial thermal destruction: " . . . the increase in cost does not justify the negligible increase in protection to human health and the environment." Also, regarding implementability: "Onsite incineration remedies . . . will require relatively more attention during design than other remedies . . . and were therefore rated lower than the other alternatives." That is, treatment requires more work than waste containment.

2) Accurate assessment of land disposal and containment alternatives.—Regarding short-term health effects for capping, there are " . . . essentially no risks to workers or residents." For long-term effectiveness, the remedy " . . . will successfully reduce long term risks to human health and the environment." Standard operation and maintenance for site and cap was planned. Regarding future actions: "No future remedial actions are anticipated. *The selected remedial action is considered permanent*" (emphasis added).

The selected capping remedy, was given two higher levels of ranking for reduction of toxicity and volume of waste as compared to the no action alternative, even though capping does no more to waste than no action. Ratings for the reduction of mobility for the selected remedy are probably too high, especially because it is not certain whether or not groundwater movement would be affected.

Several other areas of uncertainty remain:

- "Future land use considerations will be evaluated in the upcoming design phase based on the needs of protection of the cap."
- That some water infiltration through the cap, which would cause migration of contaminants into groundwater, might happen is indicated by the possible use of a synthetic liner in the cap: "The long term advantage to the liner is that *less* water would be generated from the seeps" (emphasis added).
- With regard to long-term impacts: "The potential for future fires and continued offsite migration of contaminants pose adverse human health and environmental impacts. *Other impacts which the site may pose cannot be effectively predicted.* A RCRA cap and groundwater treatment would mitigate these problems as well as most of the unseen, long term problems" (emphasis added).

In the FS for the Pristine site in Ohio, landfilling the contaminated soil was rejected "Because there is no treatment of soils to reduce the mobility, toxicity or volume [it] is *not a permanent remedy* . . . and [it] is the least preferred under SARA" (emphasis added). In the FS for the French Limited site (in the same EPA region as Compass), use of a slurry wall and cap to contain hazardous waste was described as a "temporary solution" for which the "volume and toxicity would not be affected" and "the potential would always exist for failure of either the cap or the slurry wall allowing for the movement of unstabilized wastes contained onsite."

RIFS contractor.—State led, $624,000; John Mathes & Associates.

State concurrence.—"The State . . . has concurred with the capping portion of this remedy. . . . the State did not support any of the other proposed remedies."

Community acceptance.—" . . . the public was in favor of [capping] over thermal treatment of the waste. . . . the public concern was that the thermal treatment unit would create hazardous emissions and increase the potential for exposure."

Special comments:

- No treatment technology other than thermal destruction was considered in the final analysis, although other possibilities existed.
- No commitment to using a liner was made even though " . . . Subtitle C of the Resource Conservation and Recovery Act, which requires a cap with liner, is relevant and appropriate."
- No specific technical criteria were used for deciding what types and levels of contamination found via groundwater monitoring would trigger actual groundwater treatment. There was no comment on level of certainty that groundwater monitoring would in fact detect plumes of contamination.
- No consideration was given to the effect of leaving wastes in the ground and to the effect of contaminants that have already migrated into the subsurface. These subsurface contaminants can cause future contamination of groundwater that moves into and through the site area and eventually into the Arkansas river, even though

capping reduces water infiltration through the site surface.

- Although the ROD acknowledged the SARA requirement to review the chosen remedy, which leaves waste onsite, every five years, there is no explicit commitment to doing so.

General conclusions.—The remedy selected (capping) and its supporting analysis do not satisfy statutory requirements on remedy selection. The selected remedy is not, as the ROD asserted, a permanent remedy. A number of statements in the ROD contradict the claim of permanency. For example, the possibility clearly exists for future remedial action because wastes are left untreated in the ground: "If however, future migration does occur appropriate remedial actions will be taken." The long-term uncertainties, the potential environmental risks, and future cleanup costs for capping have not been examined. Moreover, the perspective on land disposal and capping in this ROD is inconsistent with work at other Superfund sites.

EPA said that the selected remedy is less environmentally effective than thermal destruction; therefore, the chosen remedy is less cost-effective. Despite the extremely high cost of total incineration, the issue of the environmental effectiveness of capping remains. If capping is not effective, then its lower, more attractive cost does not make it cost-effective and does not make it a permanent remedy. It is not an either-or situation.

To reduce cost, the partial incineration option of hot spots of contamination could have been a compromise option. Perhaps spending two to three times more money than capping, instead of 20 to 30 times more for complete incineration, could have provided a permanent, cost-effective remedy. The ROD suggested that the site area is some 100 acres, but a statement in the responsiveness summary refers to 32 acres for the cap. In either case, the amount of soil sampling at the site—28 locations—was insufficient to accurately characterize contaminant distribution. (Assuming there are 32 acres, sampling is about one location per acre. For comparison, at the Renora site in New Jersey, sampling was done in 12 locations per acre; at the Seymour Recycling site in Indiana, it was six locations per acre; and at the Tacoma Tar Pits site in Washington, it was one-and-a-half locations per acre.) Hence, there was insufficient data to consider how partial excavation and incineration for the most contaminated areas might be cost-effective.

Doing enough soil sampling to assess a site accurately enough to detect hot spots has been studied by EPA. Soil sampling is a major effort: "Systematic sample site selection is normally used when attempting to determine areal extent of contamination or when evaluating spatial variations. Sampling locations are defined by a grid or coordinate system and samples are collected at preselected locations in a uniform pattern." (R.J. Bruner, "A Review of Quality Control Considerations in Soil Sampling," *Quality Control in Remedial Site Investigation*, American Society for Testing and Materials, 1986, pp. 35-42.) The critical tradeoff between the cost of taking more or less cleanup action has been summed up by EPA: "If the cost of a false positive (incremental cleanup of additional area) is less than the cost of a false negative (health risk due to not cleaning an area), then the larger probability of false positive is acceptable. If the [contaminant concentration action level] were raised, the probability of false positives (unnecessary cleanup) would be lessened, but with an increase in the probability of a false negative (leaving a 'dirty' area)." (G.T. Flatman, "Design of Soil Sampling Programs: Statistical Considerations," *Quality Control in Remedial Site Investigation*, American Society for Testing and Materials, 1986, pp. 43-56.) The latter happens when average site concentrations are used to decide what cleanup to perform, because the average value is below the action level. If hot spots are found, their concentrations will be above the action level and false negative (dirty) areas, as well as false positive (clean) areas, are avoided; that is, dirty areas are cleaned, but clean areas are not.

At the Compass site, another strategy could have been to delay cleanup or to see capping as an interim remedy until more work could be done to fully examine alternative treatment technologies. The large amount of waste at the site poses a difficult problem for which some innovative cleanup technologies, including in situ techniques to avoid excavation, could have been considered and examined in treatability studies.

Why the State and the community chose capping, an impermanent and incomplete remedy, over incineration and groundwater treatment, which are permanent and complete, is not entirely clear. But avoidance of higher costs and pessimism about the safety of incineration seem to be the critical factors. Concerns about incineration can be addressed through effective communication of state-of-the-art incineration technology including effective pollution control technology. The concern about enormous cost for incineration could have been addressed through either the hot spot or search for alternative treatment strategies.

Actually, the groundwater contamination problem did not get enough attention, as capping cannot completely stop further contamination. (The ROD had a tacit acknowledgment of a carcinogenic risk factor of 1 in 100,000 for contaminant migration through groundwater seeps entering the Arkansas River. It is not certain that the cap alone, or even in combination with groundwater cleanup, would permanently reduce this to EPA's typical goal of limiting risk to 1 in 1 million.)

This site also illustrates a subtle and largely ignored issue in Superfund cleanups—cumulative risk. To what extent is a cleanup at one site planned relative to neighboring cleanup sites that can contribute environmental risk to the same population? Assessment of environmental risk at only one Superfund site seldom acknowledges human exposures from another site and, therefore, what seems for one site to be a safe level of contamination, exposure, and risk may not be so cumulatively. The Compass Industries site and the Sand Springs Petrochemical Complex Superfund site face each other across the Arkansas River. The migration of contaminated groundwater into the river from *both* sites would increase the danger to the same downstream users.

Case Study 3
Conservation Chemical Company, Kansas City, Missouri, EPA Region 7

Capsule OTA findings.—A hydraulic containment system to pump and treat some contaminated groundwater and capping of the site were chosen over the alternative of excavating and treating contaminated soil and buried wastes, which was recommended in an EPA study and by the State. Water treatment cannot remove all the diverse contaminants at the site. No estimate was said to be possible for the duration of the cleanup.

Key dates:

- Entered Superfund system: 1/1/79
- Preliminary Assessment: 3/1/79
- Site Inspection: 3/1/79 - 11/1/80
- National Priorities List
  —proposed date: 4/1/85
  —final date: none
  —site rank: none
- RIFS start and completion: Complex history of studies by PRPs and EPA
- Public comment period before Record of Decision: 3/26/87 - 5/8/87
- Signing of ROD: 9/30/87
- Estimated complete remediation: none possible

Total time.—Unpredicted but probably a very long time—decades.

Brief description of site.—"The site is approximately 6 acres in size and is situated on the floodplain of the Missouri River near the confluence of the Missouri and Blue Rivers, on the river side of the levee. [The aquifer under the site] is used as a source of drinking water by both private residents and public water supply companies."

"Waste disposal operations began [in 1960] and continued until approximately 1980. CCC employed a variety of waste handling practices, including but not limited to solvent incineration, solvent resale, pickle liquor neutralization, cyanide complexation, chromic acid reduction, and ferric chloride/ferric sulfate recovery. Residual materials from the various treatment processes were generally disposed of on site in the basins. Drums, bulk liquids, sludges, and solids were buried at the site. Some wastes, such as drummed cyanide wastes and arsenic and phosphorus containing wastes, were disposed of on site without treatment. . . . approximately 93,000 cubic yards of materials are buried on site."

Major contamination/environmental threat.—There are 21 substances "substantially in excess of applicable criteria or standards for water quality. These include six metals, cyanide, four phenolic compounds, and 10 volatile organic compounds (VOCs)." Other substances "cause concern for aquatic life." Also, dioxin was detected at levels up to 29 parts per billion (ppb). (A level of 1 ppb has been EPA's guideline for soil cleanup.)

The greatest risk comes from the use of contaminated groundwater. Next is the risk from contaminated soils, which may be "transported by precipitation runoff into surface water bodies or the groundwater. Contaminated soils also present hazards from direct contact and wind dispersion of particulates."

"[The] groundwater is considered to be a current drinking water source since groundwater is used for drinking water within a two mile radius of the site."

HRS scores.—groundwater 51.02; surface water 9.45; air 0.00; total 29.99.

Removal actions.—None indicated in ROD; SCAP indicated over $2 million spent on removal, starting in 1985.

Cleanup remedy selected.—This remedial cleanup is the third selected for the site. The first cleanup, done by the original owner, was discovered in 1985 to have failed. The State had approved a closure "which called for the addition of absorbents and cementing materials to the waste in the uppermost 5 feet of each basin. Waste acids, predominantly pickle liquor, and fly ash were mixed with the upper layer of waste materials in the basins. Tests conducted in 1985 indicated that the desired pozzolonic cement-like properties have not formed. Also there are indications that this material has deteriorated and will continue to deteriorate."

The 1987 ROD indicated a previous ROD in mid-1985 that adopted a circumferential containment approach with interior pumping. But its implementation was stopped in 1986 when geotechnical investigations found that the depth to bedrock ranged so high (to 160 feet) that "the construction of a circumferential impermeable barrier could be more difficult than originally believed." (Neither SCAP or EPA's master list of all RODs indicates an earlier ROD for this site.)

Many cleanup alternatives for the Conservation Chemical site have been examined, and most have been eliminated. Because the enactment of SARA came after the initial studies, EPA performed two more studies in 1987. However, the current ROD evaluated only three main cleanup alternatives in what is a well-structured and well-presented analysis: 1) the 1985 remedy, 2) onsite containment of contaminants by onsite pumping and groundwater treatment, and 3) excavation followed by soil treatment.

The 1987 ROD chose a remedy that includes: 1) the use of a permeable cap to allow water intrusion to assist groundwater cleanup; 2) a withdrawal well system to achieve an inward groundwater gradient; 3) a groundwater treatment system based on several unit operations, including "at a minimum, such treatment processes as metals precipitation (utilizing both hydroxide and sulfide precipitation), filtration, biological treatment, and carbon absorption"; and 4) offsite groundwater monitoring. Some descriptions of the chosen remedy from the ROD on the selected remedy are:

- " . . . relies on hydraulic, rather than structural, containment to prevent migration of contaminants from the site."
- "Although designed primarily for containing the on-site contaminants, [it] would also clean up a portion of the off site contamination."
- "While the treatment technologies that will be employed provide high levels of treatment, they do not remove 100 percent of the contaminants."
- "This cleanup process could take a substantial time period."

- "There is no methodology available to estimate the length of time required for cleanup."
- "This cleanup would include the discharge of acceptable levels of contaminants remaining in the groundwater after treatment to surface waters and the need to dispose of solid wastes resulting from the groundwater treatment processes."
- ". . . because an active pumping system relies upon the use of currently available technology, which can be constructed in the shortest time frame, this alternative would provide expeditious implementation of the remedial action with substantial certainty as to its effectiveness in protecting public health and the environment."
- ". . . may prove to be the least costly remedy that would meet the environmental goals and requirements of CERCLA."

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The ROD said the selected remedy "is cost-effective, consistent with a permanent remedy [and] applies permanent solutions and alternative treatment technologies to the maximum extent practicable." On the issue of permanency: "Contaminants present at the site will be contained at the site, thereby eliminating further uncontrolled releases into the environment." Also: "Treatment of hazardous substances to reduce their volume, toxicity and mobility by treating the extracted groundwater is the principal element of [the selected remedy] . . . the uncertainties of [the soil treatment alternative's] technical feasibility at this site raise substantial question as to its practicability. Extensive research would be necessary prior to its implementation to resolve this question. For these reasons, [the selected remedy] offers treatment to the maximum extent practicable."

The selected groundwater treatment part of the remedy, however, does not involve destruction technology to a large extent. Most of the unit processes are separation technologies. The result is the generation of hazardous sludges requiring management and the discharge of contaminants to the air. Moreover, no attempt was made to estimate the duration of the groundwater cleanup. Such estimates have been made at other Superfund sites. If there is insufficient data to make such an estimate, then there is a remarkable degree of uncertainty about the functioning of the groundwater pump and treat approach.

The important feature of the selected remedy is that it does not directly deal with the contaminated soil and buried wastes on site. Drawing water through the site, or flushing, is not likely to remove all contaminants. Depending on soil conditions and what chemicals are present, some contaminants are difficult to remove by flushing. It is difficult to conceive of water drawn through the site's hazardous materials being able to dissolve or otherwise remove all the diverse contaminants at the Conservation Chemical site. And what will happen when the pumping is stopped? Indeed, the ROD did not claim complete removal of the site's contamination.

The ineffectiveness of flushing was shown at tests at the Volk Field Air Force site in Wisconsin. EPA laboratory research on the use of surfactants to remove organic contaminants from soil had been successful. However, the field study found that in situ soil washing with aqueous surfactants "was not measurably effective." (U.S. Environmental Protection Agency, "Project Summary—Field Studies of In Situ Soil Washing," February 1988.)

The selected remedy leaves a very large amount of untreated hazardous material on the site. The ROD said that protection against the risk posed by contaminated soil will be addressed first by the permeable cap on the site during the pump and treat stage and second by the placement of a RCRA cap upon completion of the groundwater cleanup. Limiting site access is also offered as a means of minimizing risk. Regarding the dioxin contamination: "Since all the [dioxin] containing samples were obtained from sludge and surface soil samples, the waste containment strategy and surface cap will minimize possible contact with TCDD."

A major issue for the Conservation Chemical site is the rejection of the alternative of excavation followed by soil treatment, which an

EPA contractor recommended in a special study for Superfund's enforcement program (Jacobs Engineering, "Analysis of Alternative Remedial Action For The Conservation Chemical Co. Site, Kansas City, MO," March 1987.). The study concluded: "The only treatment method which would meet the environmental protection goal (of permanent removal or detoxification of contaminants), and therefore the only method likely to gain public acceptance, is excavation followed by soil treatment. Therefore, we recommend that excavation followed by soil treatment be considered as an alternative treatment technology, under the requirements of SARA, for implementation at the CCC site." Admittedly, the study dealt with soil treatment or washing in general terms. Moreover, even this treatment is a separation technology which would, like the selected groundwater treatment, produce concentrated residues which would have to be managed. Overall, the study was an excellent analysis of cleanup alternatives and carefully considered the pros and cons of a number of options including in situ bioreclamation, in situ soil flushing, and excavation followed by landfilling. The ROD included the recommended alternative but consistently evaluated it more negatively than the selected remedy. Some relevant ROD comments supporting rejection of soil treatment are:

- On reliability: "while [it] could be implemented, extensive testing and studies would be necessary to verify this prior to implementation."
- On implementability: "[it] applies a new technology and, as a result, there are substantial uncertainties associated with implementation of this alternative which may take considerable time to resolve before this alternative could be implemented"
- On technical effectiveness: "There are still unresolved uncertainties associated with the technical effectiveness of [soil treatment]."
- On environmental concerns: The ROD noted that there would be short-term impacts because of excavation which could be minimized but not eliminated. "The option also involves the discharge of low levels of contaminants and the generation of treatment plant sludges requiring disposal."
- On safety: "The potential safety risks for [it] appear to be greater."
- On public acceptance: "the alternatives are generally equivalent based on anticipated public acceptance." (A very different statement than one in the Jacobs Engineering report.)
- On cost: The ROD's estimated cost of the selected remedy is $21 million and for soil treatment $24 million. "While there are a number of uncertainties for each alternative . . . [they are] the greatest for [soil treatment]."
- On operation and maintenance: "[Soil treatment], if feasible, should require a substantially shorter period of operation and maintenance than [the others]."

2) Accurate assessment of land disposal and containment alternatives.—Although there is a groundwater treatment component to the selected remedy, the cleanup rests on containment of the hazardous materials that are the source of the groundwater contamination. There was no significant analysis of the long-term uncertainties and possible failures of the containment and capping aspects of the cleanup. Considering the proximity of the site to both surface and groundwater, this lack of analysis is a major shortcoming of the selected remedy.

In the FS for the French Limited site in Texas, use of a slurry wall and cap to contain hazardous waste was described as a "temporary solution" for which the "volume and toxicity would not be affected . . . [and] . . . the potential would always exist for failure of either the cap or the slurry wall allowing for the movement of unstabilized wastes contained onsite."

RIFS contractor.—Information on the complex RIFS history is missing. However, the SCAP notes that on 5/21/87 there was an EPA takeover of the RIFS, but the takeover came after the RIFS reports were completed.

State concurrence.—The front of the ROD said: "The State of Missouri has been consulted on the selected remedy." In the responsiveness summary at the end of the ROD, reference was made to a written comment by the Director, Division of Environmental Quality, Missouri

Department of Natural Resources: "The Missouri Department of Natural Resources recommends the alternative incorporating excavation of the wastes and soil washing with downgradient groundwater pumping and treatment be utilized for the remedial action at the CCC site. The commentor stated that this recommendation is consistent with the final recommendation contained in an EPA contractor's report on alternative remedial action technologies at the CCC site." The ROD contained a copy of an internal EPA memo stating that EPA headquarters and the Department of Justice support the selected remedy.

Community acceptance.—The ROD said that there was a "low level of community concern. No major public concerns have been received at this time." One comment noted in the responsiveness summary is from the Coalition for the Environment, Kansas City. The questions touched upon the length of time for the groundwater cleanup.

Special comments.—The ROD says: "Total risk from all carcinogens should be between one in ten thousand to one in ten million." This is a very broad range which could mean that actual risks associated with cleanup goals might be 100 times as great as the 1 in 1 million level used most frequently by EPA.

The site's HRS groundwater score seems low in the context of the information in the ROD on what contaminants are present and the use of the aquifer for drinking water.

General conclusions.—Contrary to what the ROD concludes, the selected remedy does not offer a permanent remedy which effectively reduces the toxicity of the site's contaminants. Contaminant volume would decrease somewhat through groundwater treatment, because groundwater moving through the site would flush some contaminants from the soil. Groundwater treatment, for the most part, removes some unknown amount of contaminants which may be landfilled somewhere else or may be discharged into the air.

Although the soil excavation and treatment alternative is not a true destruction approach, it is more consistent with the intent of SARA, as the EPA contractor report also concluded. The cleanup selected for the Seymour Recycling site in Indiana sets a better example because it includes two components to treat site contaminants in addition to the pump and treat component for the groundwater.

The rejection of the soil excavation and treatment alternative seems to be based on uncertainty about its effectiveness. This uncertainty exists because no treatability study was conducted as part of the RIFS. But this uncertainty must be balanced against the uncertainties of the selected pump and treat remedy: How long will water be pumped and treated? What contaminants in what amounts will be removed and what will remain on site? How protective is the cap on the site? What is the ability of the hydraulic containment system to prevent contaminants from moving off site in the groundwater? Also, although the pump and treat can be started sooner, the ROD acknowledged that the soil treatment remedy could be completed in a much shorter time.

Many uncertainties weaken the claim that the selected remedy is cost-effective. Even if a treatability study for soil treatment was successful, the selected remedy—with its comparable uncertainties—would not offer the same overall level of long-term environmental protection. Therefore, regardless of cost, it would not be cost-effective.

The rejected soil treatment alternative ($24 million) was estimated to cost about the same as the selected remedy ($21 million). However, because soil treatment was only discussed in general terms, its cost is highly uncertain, especially when compared to the selected remedy which uses off-the-shelf equipment. The estimated cost of the soil treatment alternative was probably underestimated. Indeed, for a similar cleanup at the Chemical Control site the cost of soil treatment was about the same as for Conservation Chemical, even though the amount of material treated at Chemical Control (some 20,000 cubic yards) was a small fraction of that at Conservation Chemical (the ROD indicated about 100,000 cubic yards).

EPA's contractor report on alternative remedial action at Conservation Chemical used a figure of 298,000 cubic yards for contaminated soil to be treated and included about $5 million (out of about $20 million) for groundwater pumping and treatment. Thus, the average cost for cleaning the excavated soil was about $50 per cubic yard, a very low price for any kind of contaminated soil treatment. (The ROD did not contain any theoretical or experimental data to show that a very simple form of soil washing could be effective in removing a diverse set of contaminants.)

The cost of the rejected alternative can be recalculated in two ways. First, the unit cost of the treatment can be altered and a range considered for the amount of material to be treated. A figure of $500 per cubic yard is comparable to an estimate for a similar cleanup in the FS for the Chemical Control site and for the Re-Solve site. The FS for the Crystal City site had a cost of over $1,000 per cubic yard for a soil washing alternative for both organic contaminants and arsenic. And a company with a mobile soil washing technology, not applicable to metal contaminants, has indicated a cost of $450 to $1200 per cubic yard. (Tufts University, "Transportable Treatment Unit Technologies," July 1986.)

The ROD acknowledges the uncertainty about onsite contaminants. If it is assumed that about 100,000 cubic yards of material would be excavated and treated (a figure consistent with information in the ROD), then, at a unit cost of $500 per cubic yard, the total cost would be about $50 million, about twice what was estimated. For the figure of 298,000 cubic yards from the 1985 and 1987 studies and the cost of $500 per cubic yard, the total cost is $150 million. Thus, the range is $50 to $150 million.

A second way to recalculate is to ask whether an estimate closer to the ROD's can be obtained? If a volume of contaminated material halfway between the two estimates in the reports is assumed (200,000 cubic yards) and the calculation is based on a unit cost of soil treatment at $200 per cubic yard (between the optimistic value of $50 per cubic yard and the above $500 per cubic yard), the total is $40 million. In this conservative scenario the cost is still about twice that used in the ROD.

The attractiveness of the selected remedy, therefore, rested in part on its certain cost of $21 million relative to the underestimated cost of $24 million for the soil treatment option. The comparable ROD costs appear to remove low cost as a deciding factor. Would the selected remedy seem less attractive from the SARA perspective of preferring a permanent remedy if the soil treatment option was significantly higher in cost? True, there is a legitimate issue for excavating materials and the risks associated with it. But such excavation has been selected at other sites because there are established techniques to mitigate such risks (e.g., wetting materials to avoid dust). A technical case for not excavating materials, given for the Seymour Recycling site in Indiana because of large amounts of volatile chemicals, was not made for Conservation Chemical.

Finally, this case may illustrate the lack of management oversight of RIFSs and RODs in the Superfund program (even if the case does not indicate a high level of interest in reaching a settlement with the PRPs). Even a cursory examination of the data for and of the uncertainties about the volume of treated material and cost would probably have spotted the cost under estimate for the soil treatment alternative.

Case Study 4
Crystal City Airport, Crystal City, Texas, EPA Region 6

Capsule OTA findings.—Excavation of contaminated soils and wastes (which were buried in a previous removal action) and their disposal in an unlined landfill with a cap over it were selected over incineration. No treatability study supported the conclusion that the selected remedy is permanent on the basis of the adsorption of diverse contaminants to site soil. Major failure modes for the landfill were not examined.

Key dates:

- Entered Superfund system: 8/1/83
- Preliminary Assessment: 3/1/87
- Site Inspection: 9/1/84
- National Priorities List

- —proposed date: 10/84
- —final date: 6/86
- —site rank: #639 out of 770

- RIFS start and completion: 9/28/85 to 7/13/87
- Public comment period before Record of Decision: 8/10/87 to 9/14/87
- Signing of ROD: 9/29/87
- Estimated complete remediation: 8/89

Total time.—6 years

Brief description of site.—"The site is comprised of approximately 120 acres of land. Surrounding the airport property . . . is land used for grazing animals . . . a municipal landfill . . . an elementary and high school as well as a residential area . . . Since 1949 the city has operated the facility as a municipal airport. Several private companies conducted aerial pesticide applicating businesses at the airport until 1982."

Major contamination/environmental threat.—"The estimated volume of contaminated soil exceeding 100 parts per million (ppm) total pesticide is 12,000 cubic yards." Although a large number of contaminants have been detected, "The contaminants of greatest concern at the site (toxaphene, DDT, and arsenic) were chosen from the compounds detected based on their widespread distribution over the entire site as well as the relative toxicity and concentration." There are also buried materials from an earlier removal action and contaminated buildings. Direct contact, surface water, and air emissions are major routes of exposure. The worst case exposure scenario is for residents of a nearby housing project.

HRS scores.—groundwater 33.01; surface water 12.92; air 43.08; total 32.26

Removal actions.—Immediate removal: 10/31/83 to 11/8/83 for $33,000; 40 cubic yards of waste and between 50 and 70 drums of material were buried in two onsite landfill cells. Second removal: 4/24/84 to 4/25/84 for $25,000; 19 drums (FS says 21 drums) were buried in an offsite landfill, the site was fenced, warning signs were posted, and according to the FS: "eroded areas of the clay caps were repaired."

Cleanup remedy selected.—In addition to a number of containment alternatives, incineration and critical pressure fluid extraction were evaluated. The ROD described the remedy as: "Onsite consolidation of all material which exceeds the health-based criteria of 100 milligrams per kilogram (mg/kg) total pesticides. Placement of a RCRA cap over the consolidation cell. Monitor site for a minimum of 30 years following construction of selected remedy. Deep-well injection of decontamination liquids. Five year review of selected remedy." The argument was made that "By consolidating the contaminated soil away from the runway and taxiways, land use could be maintained." Estimated cost: $1.6 million.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—"The selected remedial action is considered permanent. Consolidating this 'naturally treated' waste under a hazardous waste cap is . . . considered permanent." However, while the ROD did not say that an alternative treatment technology was selected, which it was not, the ROD did suggest that alternative treatment would be "inappropriate." No reduction in toxicity or volume was claimed and the ROD correctly noted that these reductions are "not a requirement of the [SARA] provision." The ROD said that incineration "did not conform with the Superfund statute as well as the consolidation/capping remedy" and that health and environmental protection is equal for incineration and consolidation/capping alternatives.

The ROD's case for permanency for consolidation/capping rested on these facts:

- " . . . soils [are] characterized by high clay content and extremely low permeabilities."
- " . . . [the] aquifer is located 750 feet below the surface of the site and is isolated from the contaminated surface soils of the site by thick clay layers."
- " . . . contaminants are already highly immobilized and fixed within a solid soil matrix."
- " . . . arsenic and organic pesticides [are] locked into [the] top foot of the alkaline soils at the site."

- "The degree that contaminants are bound up is of the same degree that would have been achieved if the pure contaminants had been processed by a solidification technology."

The permanence of consolidation/capping is uncertain for two reasons. First, no sound technical case was made that all of the diverse range of contaminants would be adsorbed tightly to the site soil. A treatability study could have been conducted to demonstrate whether significant leaching of contaminants is likely. No liner will be used to separate the waste from underlying soil. Data on the contaminants and the soil are pertinent. For example: "The primary indicator used to determine the degree to which an organic contaminant binds to soil particles is the organic carbon partition coefficient (Koc). A higher Koc for an organic compound indicates a greater tendency to adsorb to organic particles in soils, although migration may still occur throughout the site." (Feasibility Study for the Renora site in New Jersey.) Koc data are in the FS for Crystal City but were not fully discussed; site contaminants vary remarkably (by a factor of a million) and some contaminants have low Koc values which suggest poor absorption and the ability to migrate.

Mineral surfaces can also greatly affect the mobility of an organic contaminant. A research paper that found no adsorption of phenol to a mineral has noted the problem of uncertainty about adsorption of organic compounds to clays: "Hemphill and Swanson found phenol adsorption on untreated kaolinite, montmorillonite, and illite. Others did not find any phenol adsorption on untreated clays. Luh and Baker, however, did discover significant adsorption by clays for substituted phenols . . . " (E.C. Yost and M.A. Anderson, *Environ. Sci. Technol.*, vol. 18, pp. 101-106, 1984.) Another research paper that examined the interactions between organic compounds and clay minerals concluded that in relation to ideal, laboratory conditions "rates and selectivity may be different and difficult to predict under environmental conditions." (E.A. Voudrias and M. Reinhard, *Geochemical Processes at Mineral Surfaces*, ACS Symposium Series 323, September 1985.) This uncertainty about adsorption is why a treatability study on actual site contaminants and site materials would be necessary to verify that some form of effective natural stabilization would take place at the site.

A complication at the Crystal City site is the presence of solvents that can affect the adsorption of other contaminants. EPA research concluded that " . . . the effects of solvents in hazardous waste contaminated soils may include two factors: 1) decrease in total sorption to soils, and 2) increase in leaching potential through changes in soil structure." (U.S. Environmental Protection Agency, *Review of In-Place Treatment Techniques for Contaminated Surface Soils*, vol. 2, November 1984.) Also, the FS did not say whether any work was done to identify the form(s) of arsenic at the site. The ability of arsenic to remain immobilized because of adsorption to soil is not straightforward. Of the two chemical forms of arsenic, the more toxic arsenite is more mobile than arsenate and adsorption is affected by the presence of certain metals in the soil and by the pH which can change over time. (U.S. Environmental Protection Agency, *Review of In-Place Treatment Techniques for Contaminated Surface Soils*, vol. 2, November 1984.)

Second, not all the site's contaminants are planned to be consolidated. The FS indicated that only half the site's contaminated soil might be capped. The choice of the cleanup criterion of 100 ppm of total pesticide in combination with the decision to continue to allow the site to be used as a municipal airport is questionable. The ROD said that the cancer risk approaches 1 in 100,000 for onsite exposure of 220 days a year, which is possible for onsite workers and which is a higher risk than is the 1 in 1 million usually sought by EPA. Moreover, the FS indicated that a significant health threat would persist if site use was not "limited to 10 to 15 days per year." This issue is important because of the absence of future land use restrictions.

Moreover, no cleanup criterion was established for arsenic, which is significant because in correspondence to government officials EPA said: "Of the two types of contaminants, arsenic compounds predominate, are more toxic, and more persistent in the environment [than organic pesticides]." EPA also described arsenic as "the most toxic contaminant" at the site. Also, risks for inhalable dust particles may be incorrect because such small particles were not tested to determine actual level of contamination.

On the subject of incineration, the ROD said: "Treatment will not significantly reduce the mobility of the contaminants due to both the characteristics of the contaminants as well as the impermeable nature of the soils." In fact, incineration would have offered more certain permanence. The case against incineration is flawed for several reasons.

The ROD said: "A secondary treatment technology (soil washing) would be necessary to remove the arsenic compounds from the 'treated' soil." However, no consideration was given to the proven feasibility of using chemical fixation or stabilization for arsenic in incinerator ash followed by landfilling. There is considerable information to support this approach. In August 1987, EPA published extensive information in the *Federal Register* on effective treatment of arsenic in the context of the Resource Conservation and Recovery Act regulatory program. EPA said that "all the available data show that the [Extraction Procedure] regulatory level of 5.0 [milligrams per liter] for arsenic can be achieved." (52 Federal Register 29992; Aug. 12, 1987.)

Treatability tests for solvent extraction and chemical fixation of arsenic contaminated soil and sediment from the Vineland Chemical Co. Superfund site in New Jersey have been successful. (These tests were done for the same RIFS contractor as at Crystal City. The reports were filed in December 1987, although the tests were probably planned and executed much earlier.) For some time, a commercial chemical fixation company has made available extensive data on the effectiveness of its treatment on relatively high levels of arsenic in incinerator ash. Treatment costs were said to be between $30 and $55 per ton. (Chemfix Technologies, Inc., testimony before House Subcommittee on Transportation, Tourism, and Hazardous Materials, Dec. 7, 1987.) Arsenic is a contaminant at the Tacoma Tar Pits site in Washington, where stabilization was selected. Moreover, within the same EPA region as Crystal City, the ROD for the French Limited site in Texas said: "The PCBs and arsenic can be controlled by stabilization of the treatment residues."

Biological treatment for arsenic is another alternative that could have been examined in a treatability study. Then it would be unnecessary to design a "custom (innovative) system." A recent report said: "Arsenic compounds tend to be converted by bacteria into volatile forms that disperse to harmlessly low concentrations." (R.U. Ayres, et al., *Toxic Chemicals, Health, and the Environment*, The Johns Hopkins University Press, 1987, pp. 38-70.) However, not all bacteria could treat arsenic and some development would probably be necessary.

A third alternative is a thermal treatment and recycling facility in Louisiana which has been used to treat a number of cleanup waste soils and sludges. The treatment facility can handle very large volumes of hazardous waste. Its unique process would result in a residual material which appears to safely contain residual metals, such as stabilization does. Moreover, the cost is reported to be relatively low; transportation costs must be added, but even then the total costs might be competitive to mobile incineration with the added advantage that the cleanup at Crystal City might be done quickly.

Moreover, OTA has examined a removal action at Southern Crop Services in Delray Beach, Florida, (not an NPL site) in which mobile incineration was selected for cleanup of the same type of pesticide and arsenic contamination. The Florida site has the same history as Crystal City Airport. EPA noted that a "naturally rich organic layer near the surface of the soil" explains why the pesticides are concentrated and localized and why downward migration of the pesticides into groundwater has been slowed. (U.S. Environmental Protection Agency, Region 4, "Action Memorandum" for Southern Crop Services site, Sept. 8, 1987.) As much as 5,000 cubic yards of contaminated soil over 2.5 acres will be incinerated at a maximum cost of $2.5 million. *The EPA document made no mention of any problem with arsenic in the incinerator ash.* The cost of the incineration is estimated at $300 to $500 per cubic yard. Setup of the mobile incinerator was to begin in November 1987 with completion in August 1988. An EPA Headquarters review on October 9, 1987, of the memorandum by the Regional office added the following: "It was determined that on-site incineration was the most suitable method to clean up the site because it destroys the hazardous waste and eliminates the need to transport the waste off-site." This memorandum also added that, relative to offsite land disposal at half the cost of incineration, the "additional cost is considered reasonable because incineration provides a permanent solution." Moreover, EPA said: "The disposal of the waste in a landfill represents a less permanent solution to the problem than incineration, and is therefore less desirable in light of SARA emphasis on more permanent solutions."

At Crystal City Airport, the estimated cost of the incineration option of $10.8 million may have been over estimated; $2.9 million was for the arsenic treatment (about $200 per cubic yard). Without the special arsenic treatment, the cost of the alternative would be $7.9 million; thus the incineration option would cost about $575 per cubic yard (total, not unit cost), which is more than the cost range used for the Florida site but which agrees with the FS data for the Davis Liquid Waste site, where incineration was also selected at a cost of about $600 per cubic yard. If the expensive arsenic treatment could be substantially cut, the cost for the incineration alternative at Crystal City might decrease by more than $1.5 million. As noted above, use of the facility in Louisiana would probably reduce costs significantly more.

Moreover, there are instances where the ROD was biased against incineration and its commonly accepted benefits. For example: "organic contaminants *may* be reduced through an integrated incineration system," and "incineration would *remove* the organic contaminants from the solid" (emphasis added). The truth is that incineration would *definitely destroy* the organic contaminants.

Curiously, the alternative using chemical stabilization was analyzed for cost assuming that a lined landfill would be used for the treated material. The selected remedy uses an unlined landfill for *untreated* material. Use of a lined landfill adds an extra $700,000, a cost that was included in the stabilization option but excluded in the selected remedy of onsite consolidation.

2) Accurate assessment of land disposal and containment alternatives.—"Failure of this remedy is unlikely as long as proper maintenance of the cap is conducted." Nevertheless, many failure modes are possible but were not examined, including the gross disruption of landfilled material (disposal cell will be about 190 by 190 feet) and its dispersal due to an airplane crash, perhaps with fire and explosion; a natural disaster such as an earthquake, flood, drought, and cracking of the soil that are applicable to the site; the uptake of contaminants by biota, bioaccumulation, and ingestion by animals in the food chain; the undetected or uncorrected erosion of the cap; greatly increased downward transport through highly permeable soils due to large-scale pathways such as cracks and root holes; and the performation of cap liners by animals and bugs and the subsequent intrusion by water. Without considering these possibilities, the ROD overrates the technical feasibility of the selected remedy.

This ROD and its FS also illustrate another common problem in technology selection—the technical literature, including EPA's own, is rarely researched and cited to support conclusions. For example, in a recent report, EPA summed up good practice with caps over landfills: "Major storm events must also be considered, since even an arid region can be subjected to infrequent but major storms that cause anomalous ground saturation and percolation to a depth ordinarily not reached. Accordingly, a rather complete review of expectable storm events and their frequencies should be required in preparing the background on the hydrological system." (U.S. Environmental Protection Agency, "Project Summary—Design, Construction, and Maintenance of Cover Systems for

Hazardous Waste: An Engineering Guidance Document," November 1987.)

The ROD was ambiguous about the permanence of the selected remedy: "If however, future migration does occur, approprate actions will be taken." The term "significant unforeseen offsite contamination" was also used.

In contrast, the ROD for the Pristine site was realistic: "The lifetime of a RCRA multilayer cap is finite, and the contaminated soils will be left in place to contribute to groundwater contamination at some future time should the cap fail. . . . there are no data available on the long term effectiveness and permanence of RCRA caps." In the FS for the French Limited site (in the same EPA region as Crystal City), use of a slurry wall and cap to contain hazardous waste was described as a "temporary solution" for which the "volume and toxicity would not be affected . . . [and] . . . the potential would always exist for failure of either the cap or the slurry wall allowing for the movement of unstabilized wastes contained onsite." In comparison with Crystal City, these are prime examples of inconsistency across Superfund sites.

RIFS contractor.—State led; $218,000 ($726,000 obligated); Ebasco Services Inc.

State concurrence.—The ROD said the State "has remained silent."

Community acceptance.—The ROD indicated that the community favored incineration. There is also a lot of other evidence, because of a Congressional hearing in Crystal City on this issue (Apr. 11, 1988), that the community and others strongly opposed and continue to oppose the remedy chosen by EPA. A large number of local, State, and national government officials and organizations have requested EPA to change its decision.

Special comments.—The Preliminary Assessment was completed several years after the Site Inspection, according to CERCLIS; but SCAP indicates that the preliminary assessment started on 9/26/84, slightly after the site inspection.

The first removal action (in 1983) that buried hazardous materials set the precedent for an impermanent remedy and contributed to the need for remedial cleanup today.

Although the ROD said that "the organic compounds will continue to degrade under the cap into less toxic compounds," no actual data or analysis was given to support natural biodegradation under the conditions expected at the site.

The FS gave data that "suggests that the contaminants are migrating offsite through water/ sediment transport." This observation merits more attention and an explanation of the exact mechanism of transport.

The case for concluding that RCRA is not applicable was that "the contaminated material will be consolidated in the unit or area of contamination from which they originated." This conclusion is inconsistent with decisions at other Superfund sites and means that certain relevant aspects of RCRA on regulatory requirements for hazardous waste landfills, such as liners and leachate collection, were not applied as required by SARA.

The data on contaminant detection frequency in table 2 of the ROD were different than the data given in the FS.

The ROD said no groundwater was encountered, yet the HRS groundwater subscore is not zero.

General conclusions.—No sound technical case supported the conclusion that containing the wastes onsite constitutes a permanent remedy according to the intent of SARA. All of the contaminants may not bind tightly to the site soil, relevant regulatory requirements will not be met, health risks may be greater than normally acceptable levels, and a number of major failure modes of the containment system were not examined.

The cost of the incineration alternative was over estimated because of the residual arsenic contamination in the ash. In fact, stabilization of such a contaminant has been successfully demonstrated and is relatively low cost; biological treatment is also known to be feasible. The advantages of incineration over the selected remedy for the organic contaminants were discounted. **Moreover, in comparison to the decision to use mobile incineration at the Southern Crop Services site with a nearly identical type of pesticide and arsenic contamination, the negative view of incineration at Crystal City Airport seems inconsistent and even contrived.**

Since incineration is proven for the organic contaminants at the Crystal City site and provides better overall protection than consolidation/capping—contrary to the ROD's claim that the two choices are equal—a cost-effective remedy was not chosen. **The justification used by EPA for picking incineration at Southern Crop Services, in terms of its greater benefits over land disposal, particularly regarding permanency of remedy, undercuts the evaluation by EPA at Crystal City Airport.**

The FS analysis of treatment technologies for the Crystal City Airport illustrates a nationwide problem—current technology evaluations and the decisions based on them are not explainable by site-specific conditions. Several technologies rejected for Crystal City could have been justified as well as they were at other sites where they were chosen (and are discussed in other case studies in this report). For example, at Crystal City, in situ chemical stabilization was rejected: "Immobilization, chemical treatment, and physical treatments have not been shown to be feasible for in situ treatment of these contaminants as it is not possible to get a good, uniform, well distributed treatment." (This technology was selected for the Chemical Control site in New Jersey and elsewhere.) Biological treatment was rejected: "[it] is generally ineffective for destroying these wastes as the treatment is not performed in a controlled environment. Several processes are being developed which show potential. However, none of these processes have been developed past the laboratory stage. Therefore, biological treatment has been ruled out." (This technology was selected for the Renora site in New Jersey.) In situ vitrification was rejected; it was selected for the Pristine site in Ohio.

The Crystal City site illustrates the problem of using a small number of indicator contaminants not just for risk assessment but also for technology selection. The effectiveness of some cleanup technologies depends on specific physical properties which can vary substantially among contaminants. There were a number of contaminants identified at Crystal City that are not likely to adsorb tightly to the soil. For example, toxaphene is far less likely to bind tightly to soil than DDT. Both DDT and toxaphene pose a problem for safeguarding water quality because both have laboratory detection limits which are above their water quality limits. (R.H. Plumb and J.R. Parolini, "Organic Contamination of Ground Water Near Hazardous Waste Disposal Sites: A Synoptic Overview," paper presented at a Geological Society of America conference, Phoenix, October 1987.) Moreover, some chemicals—particularly solvents—may affect the adsorption of others present. Adsorption of contaminants to soil was asserted to make the case that containment was similar to solidification treatment, but no analysis or treatability tests were made to confirm the hypothesis. Without such efforts, it is not reasonable to assume adsorption of all the contaminants under all future conditions.

Keeping the cost of remedial cleanup low seems to have been an important goal. The ROD indicated that no responsible party is available to pay for cleanup. The cost for the selected remedy was estimated at $1.6 million, while incineration was estimated at $11.4 million. The FS contained an unusual statement: "The cost of a cleanup technology is also a factor of concern in the primary screening step." Alternatives were kept in the analysis "if their estimated costs are not more than an order of magnitude higher than an alternative technology which performs to the same approximate extent." Generally, FSs do not cut cleanup alternatives from preliminary screening on the basis of cost.

Invoking cost is done in the ROD when a sound case can be made for equivalent environmental protection among different alternatives. Then, the issue of cost and when to estimate it takes on new importance because of SARA's requirements on technology selection. "It is difficult enough to estimate costs at this early [screening] stage of the feasibility study when 'old' technologies are involved; it is hardly prudent to try to estimate the costs of innovative technologies before a much more detailed analysis (not to mention extensive pilot testing) is performed." (D. Truitt and J. Caldwell, "Evaluation of Innovative Waste Treatment Technologies," *Waste Management Conference-Focus on the West*, Colorado State University, June 1987.) At Crystal City, the big difference between the RIFS obligation ($726,000) and the actual money spent ($218,000), if the data are correct, may also indicate that less work, such as treatability studies, was done than could have been done and should have been done to better evaluate cleanup alternatives.

Case Study 5
Industrial Excess Landfill, Uniontown, Ohio, EPA Region 5

Capsule OTA findings.—Providing alternate water to houses that have or are likely to have contaminated wells was a satisfactory interim remedial action. However, actions to address the source of contamination and to stop and treat contaminated groundwater are taking a very long time.

Key dates:

- Entered Superfund system: 12/1/80
- Preliminary Assessment: 12/1/83 (from CERCLIS); 12/9/83 (ROD)
- Site Inspection: 8/1/84 (CERCLIS); 3/5/84 (ROD)
- National Priorities List
  - —proposed date: 10/1/84
  - —final date: 6/1/86
  - —site rank: #164 out of 770
- RIFS start and completion: 12/28/84 to 8/87 (final focused FS)
- Public comment period before Record of Decision: 8/12/87 to 9/10/87
- Signing of ROD: 9/30/87

Estimated complete remediation: 12/89 for this interim remedial action. (According to the ROD, it will take 5 years to design and implement an aquifer restoration remedy. If a ROD for the final cleanup is issued by October 1988 as scheduled, the complete remedy would end in late 1993, but this estimate may be optimistic.)

Total time.—13 years

Brief description of site.—This ROD addresses an operable unit or interim remedial action of the overall remedy. "The Industrial Excess Landfill is a closed sanitary landfill . . . From 1968 to 1980 the site was operated . . . for the disposal of a variety of solid waste materials. During this time, the landfill accepted municipal, commercial, industrial, and chemical wastes of substantially undetermined and unknown composition, primarily from the rubber industry in Akron, Ohio. Large quantities of chemical and liquid waste were dumped onto the ground either from 55-gallon drums or from tanker trucks. Although much of the liquid wastes were listed as latex and oil at the time of disposal, witnesses have described the disposal of solvents and volatile industrial chemicals with foul odors." The county ordered a stop to the dumping of chemical wastes in January 1972. It was not until 1980 that a court ordered closure and a closure plan was engineered and implemented; the site was covered and seeded.

"The IEL [Industrial Excess Landfill] site is located on a tract of approximately 30 acres which had previously been the site of mining operations (sand and gravel and possibly coal). The landfill has a relatively pervious soil cover."

Major contamination/environmental threat.—"About 80 percent of the site is believed to be underlain by buried solid waste materials. There are over 400 residential homes located within a 0.5 mile radius of the landfill. . . . over long periods of time, the sand and gravel and immediately underlying bedrock at IEL will act as a single aquifer." The landfill "is located in permeable soils without an impermeable liner."

Citizen complaints prompted testing in 1983 that verified contaminated drinking water. " . . . EPA discovered contamination of several private drinking water wells near the site. The Agency determined that the cause of the contamination was the migration of hazardous substances from the Industrial Excess Landfill. . . . contaminants have migrated approximately 600 feet from the western edge of the landfill, impacting the groundwater of 10 homes. Some of the residential wells sampled contained organic contaminants (vinyl chloride and chloroethane) which are attributable to the landfill and inorganic contaminants (barium, copper, cadmium, and nickel) above background levels, also attributable to the landfill. In March 1987, U.S. EPA found levels of vinyl chloride and barium exceeding federal drinking water standards in approximately ten residential wells near the landfill."

Contamination was also found in samples from shallow monitoring wells onsite near the site borders at "levels which exceed standards . . . . the observed levels of vinyl chloride [2 to 7 parts per billion (ppb)] in 3 of the 51 wells sampled are equal to or exceed the Safe Drinking Water Act Maximum Contaminant Level (MCL) of 2 ppb . . . "

A risk assessment found risks greater than 1 in 1 million excess lifetime cancer risk.

HRS scores.—groundwater 88.46; surface water 0.00; air 0.00; total 51.13.

Removal actions.—EPA performed interim emergency actions to protect residents in the short term. The Superfund Comprehensive Accomplishments Plan (SCAP) showed that work started on 12/2/85 at a cost of $973,000. The ROD contained no summary description of exactly what was done, but there were indications of several actions, including air stripper treatment for contaminated groundwater, methane venting, and some evacuation of houses. "While the air strippers effectively deal with vinyl chloride contamination, they will not remove other hazardous substances, such as heavy metals and semi-volatile organics, which threaten to migrate from the IEL site. . . . the Agency determined to go forward with a permanent alternative water supply, rather than continuing to proceed on a piecemeal basis with air strippers, whose long-term liability to protect public health cannot be guaranteed."

Cleanup remedy selected.—"Provide alternate water to an area comprised of approximately 100 homes . . . " The cost was estimated to be around $2 million.

"The primary objective . . . is to protect human health by providing a reliable supply of safe, potable water to residents whose groundwater is currently contaminated or has the potential for being contaminated by IEL before the site itself is remediated. If unchecked, contamination will continue to migrate westward, affecting the groundwater of approximately 100 homes in a 15 year time period. U.S. EPA expects to implement a remedy for the IEL site before contaminants can migrate beyond this projected area."

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—Because of its goal to provide alternative water as an interim measure, this ROD did not examine or select treatment technologies. "A permanent remedy at IEL will almost certainly involve some sort of groundwater treatment to reduce the level of contamination."

To support the plan to provide new water for homes not yet contaminated, the ROD correctly stated that " . . . groundwater flow and contaminant migration predictions are not exact sciences, and that predictions concerning the timing and effectiveness of remedial action are not always fulfilled . . . "

But why wasn't anything done to stop the movement of the contaminated groundwater? Beyond actual source control or treatment and groundwater treatment, several interim measures would have been consistent with a final, permanent remedy. Examples include: 1) vacuum extraction and destruction of volatile organic chemicals from the site, 2) testing for and excavation of hot spots of contamination, 3) installation of a containment wall or barrier, 4) plume stabilization pumping, and 5) placement of a more impermeable cap or cover. Land use restrictions could also have been considered. Such actions might well have been taken earlier; the site has contaminated local water supplies since it was closed by court order in 1980. The site's HRS groundwater score, determined in 1984, is exceptionally high.

The ROD granted that "The statutory preference for treatment is not satisfied because this action constitutes an operable unit for the overall site remedy. Treatment alternatives for the overall site will be addressed in the comprehensive RI/FS documents."

2) Accurate assessment of land disposal and containment alternatives.—The ROD did not consider these types of alternatives, except that a de facto no action on the buried wastes meant that the original land disposal remained in effect.

RIFS contractor.—Camp Dresser and McKee; about $1 million obligated.

State concurrence.—The State of Ohio concurred with the selected remedy.

Community acceptance.—It was the community that called on government officials to take serious action in the first place. For this ROD, intense community concerns focused on getting new water for more houses and on identifying the exact source of the water.

A local newspaper, the Akron Beacon Journal, November 15, 1987, reported: "Recently . . . the EPA agreed to connect 110 homes in Uniontown to a new water supply when 1,500 were in possible danger. Fortunately, Gov. Celeste saw no reason to threaten the rest and agreed to spend state money to build a new water system for all the homes. Gov. Celeste rightly saw that any error should be on the side of safety. The federal EPA's approach seems to be the opposite. A telling example was the release of documents showing the air tests had been bungled. The documents became public only after citizens invoked the federal freedom of information law to obtain them. Information about mistakes in the air tests had been know to the EPA since Oct. 21. A responsible EPA would have informed the public immediately."

Special comments.—Any ROD signed on 9/30/87, the end of the Federal fiscal year, may have been a rush job; the ROD for IEL may have suffered accordingly. It contained an incomplete summary of the administrative record, and it did not decide on the actual alternate water source, a contentious issue locally. EPA was responding to community concerns by deferring the water decision.

In the responsiveness summary, EPA made a very interesting statement on cost-effectiveness: "U.S. EPA is required to select the less expensive alternative, given that effectiveness and *implementability* are equal" (emphasis added). Adding some factor other than effectiveness is new. It could, however, act against selecting newer cleanup technologies, which usually have not been used on a large scale.

The argument for not relying on air strippers was technically sound in view of the chemical complexity of the site contaminants.

General conclusions.—It probably will be closer to 20 years than 13 between the time the IEL site was closed and the time some form of source control and groundwater treatment is applied to the site. Is EPA correct that the selected interim remedy "is fully consistent with a permanent remedy?" Although the ROD referred to aquifer restoration, it does not mention removal of the source of contamination. While providing alternate water does not stand in the way of a permanent remedy, neither does it do anything to make the permanent cleanup easier. Indeed, this ROD acknowledged that the groundwater contamination *will* get worse. Thus, because additional interim measures *would* stop or slow down the migration and help to alleviate the source of the problem, this interim measure is not fully consistent with an ultimate permanent remedy.

The assertion that it will take 5 years to design and implement an aquifer restoration remedy was probably too optimistic and is not likely to build community confidence. Experience at similar sites suggests that groundwater cleanup can take considerably longer. For example, at the Seymour Recycling site in Indiana the groundwater treatment was estimated to take from 28 to 42 years; at the Davis Liquid Waste site in Rhode Island, it was estimated to take from 5 to 10 years; and at the Re-Solve site in Massachusetts, it was estimated to take 10 years. There is, however, no obvious alternative for groundwater cleanup at IEL. EPA has said: "The actual performance of a ground water remedial action is difficult to predict until the remedy has been implemented and operational data have been assessed." (U.S. Environmental Protection Agency, "Guidance on Remedial Actions for Contaminated Ground Water At Superfund Sites," draft, October 1986.)

Before a permanent remedy is implemented, more wells may become contaminated. Also, contaminants can migrate at substantially different rates, and, therefore, the nature of the spreading contamination can change over time. Such changes are well verified by research. (See, for example, R.L. Johnson et al., *Ground Water*, September/October 1985.) Wells that are contaminated early can get worse as new, more slowly moving contaminants reach them; wells not yet contaminated eventually see the effects of the most rapidly moving contaminants. On this point the ROD noted: "Since the publication of the FFS [Focussed Feasibility Study], recent data revealed that levels of nickel exceeded Ambient Water Quality Standards." Also, "vinyl chloride has migrated off-site quickly . . . while its parent compounds pose a threatened release from the site because they are migrating at a slower rate." The ROD also noted: "the shallow and deep aquifers are continuous and linked to one another." Therefore, the complexity of groundwater contamination and its cleanup could worsen significantly. The possibility of upgradient chemical migration should not be ruled out. (See R.H. Plumb, Jr., *Proceedings Second Canadian/American Conference on Hydrogeology*, 1985, pp. 69-77.)

The long history of the site, the extensive groundwater contamination offsite, and the delay in addressing the source of the problem is feeding community lack of confidence in government efforts and demands for new water to more houses.

Case Study 6
Pristine, Inc., Reading, Ohio, EPA Region 5

Capsule OTA findings.—In situ vitrification was developed originally for radioactive soils, but its use for chemically contaminated sites is still unproven. Without treatability test results, in situ vitrification was selected for this site chiefly because its estimated cost was about half that of onsite incineration. But the estimated cost for incineration is probably high by a factor of two. Incineration offers more certainty and probably costs no more than the selected remedy. Groundwater will be pumped and treated by air stripping and carbon adsorption.

Key dates:

- Entered Superfund system: 4/1/79
- Preliminary Assessment: 1/1/83
- Site Inspection: 9/1/82
- National Priorities List
  - —proposed date: 12/1/82
  - —final date: 9/1/83
  - —site rank: #531 out of 770
- RIFS start and completion: 9/5/84 to 11/87
- Public comment period before Record of Decision: 11/13/87 to 12/11/87
- Signing of ROD: 12/31/87

Estimated complete remediation: 8/91; 2 years for source control, 5 to 10 years for groundwater cleanup (August 1991 is given in ROD, but this seems optimistic and inconsistent with other groundwater cleanups; 10 years for groundwater cleanup is more realistic)

Total time.—20 years

Brief description of site.—The site is in a suburb of Cincinnati. The site is 2.2 acres and "is bordered by residential and industrial areas. There are two aquifers under the site." In the late 1970s, a liquid waste incinerator was operated at the site. "In April 1979, as many as 8,000 to 10,000 drums and several hundred thousand gallons of bulk liquids were on site, consisting of acids, solvents, pesticides, PCBs and other chemicals." A consent order shut down the facility in September 1981.

Major contamination/environmental threat.—". . . over 90 compounds were detected in the groundwater, soil, sediment, and surface water."

"Groundwater in the upper aquifer is contaminated primarily with volatile organic compounds (VOCs) such as benzene, vinyl chloride, tetrachloroethene (TCE), and 1,2-dichloroethane. Semi-volatile compounds (semi-VOCs) and pesticide compounds occurred in relatively lower concentrations. The lower aquifer is contaminated with benzene and 1,2-dichloroethane. There are also elevated levels of lead and fluoride."

". . . the presence of VOCs in the [Reading municipal wells] indicates that the groundwater quality in the vicinity is compromised and continued monitoring is recommended . . . The lower aquifer is the source for the regional water supply [13,000 people]." This route of exposure poses the largest risk.

"Sediment . . . and soil in the upper two feet of the site are contaminated with a variety of VOCs, semi-VOCs, and pesticides. Principal contaminants in surface soils are benzene, dieldrin, and DDT." Low levels of dioxins and furans were also found.

"Subsurface soil contained VOCs . . . There were also elevated levels of cadmium, lead, mercury and zinc."

"Surface water was contaminated with VOCs, semi-VOCs and pesticides . . . There were also elevated levels of inorganic compounds (cadmium, chromium, and mercury)."

A good risk assessment established cleanup goals at 1 in 1 million risk level. The RIFS calculated how much soil would have to be removed to "eliminate both the risk associated with adsorption and ingestion of soils and ingestion of groundwater contaminated through leaching from the soil."

HRS scores.—groundwater 60.00; surface water 10.91; air 0.00; total 35.25

Removal actions.—The site operator removed waste from June 1980 to November 1983 under a consent decree. Some responsible parties removed waste and soil from March 1984 to July 1984 under an administrative order. The ROD did not say how much material was removed, nor its disposition, but it was probably landfilled.

Cleanup remedy selected.—This ROD was a final source control remedial action but also included groundwater cleanup. Another ROD might be issued for additional groundwater cleanup.

The key component of the selected remedy is in situ vitrification (ISV) for 37,700 cubic yards of contaminated soil and sediment. ISV was chosen over onsite incineration. ISV is an innovative technique that uses electrodes in the ground to pass electricity through soil, melt it, vaporize and at least partially destroy organic chemicals, and leave in place a chemically inert, stable, glass-crystalline mixture. Temperatures in the range of 2,000 to 3,600° F are possible. Different cells of soil are melted in order to cover a site. The melt grows downward and outward as power is applied. As the vitrified zone grows, it incorporates nonvolatile elements and destroys organic components by pyrolysis. The pyrolysis byproducts migrate to the surface of the vitrified zone, where they combust in the presence of oxygen. "The estimated time required to complete the vitrification process is two years assuming the use of one vitrification unit."

Groundwater will be pumped and treated with an air stripper and carbon adsorption. That is, separation, not destruction, technology was selected. Groundwater monitoring was set up. The possibility of deed restrictions was raised. "It is estimated that it will take five to ten years to extract and treat the contaminated groundwater."

Estimated cost: $22 million.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—In its initial two screening stages, the FS examined a large number of treatment technologies. However, after more detailed screening, many of the treatment technologies said to be applicable were dropped without much justification. For example, three in situ treatment technologies passed the initial screening, but solution mining and soil vapor extraction were dropped and only vitrification was retained for more detailed analysis. Onsite treatment technologies that passed the initial screening included fixation/solidification, soil washing, and dechlorination, but only incineration was analyzed further.

The ROD said that the selected ISV remedy "will significantly reduce the mobility, toxicity, and volume of hazardous substances in the soil through treatment. The mobility of the contaminants will be reduced significantly, such that no leachate is expected to be produced from the vitrified material. This is a permanent technology, the results of which are expected to last for a million years. The toxicity of organic components will be decreased because the organics are destroyed or changed to other forms by pyrolysis or vaporization. The volume of the soil will be reduced by 25 to 30 percent because the vitrification causes the soil mass to consolidate."

A chief issue is whether or not ISV is a proven technology. ISV is an alternative treatment and an innovative technology that was developed originally for treating radioactive contaminated soils, but its use for chemical contamination raises new questions. How should ISV be classified? Is it thermal destruction or stabilization? EPA's SITE technology demonstration program categorizes it as stabilization, as do others. (N. Nelson et al., *Toxic Chemicals, Health, and the Environment*, The Johns Hopkins University Press, 1987, pp. 205-279.) Stabilization is a reasonable label because metal contaminants remain in the final glass-like material and because the leaching of metals and the complete destruction and removal of organic contaminants are uncertain. Although very high temperatures are reached, not all organic contaminants will either be destroyed or be able to escape and be captured. However, EPA also calls ISV thermal destruction. (U.S. Environmental Protection Agency, *Technical Resource Document: Treatment Technologies for Halogenated Organic Containing Wastes*, vol. 1, January 1988.) This EPA report describes ISV as: "Not commercial, further work planned. No [performance] data available, but DREs [destruction-removal efficiencies] of over six nines reported."

ISV's developer, Battelle Pacific Northwest Laboratories, which supports ISV's inclusion in SITE, has commented on treatability testing: "While the results are promising, feasibility testing to confirm applicability is strongly recommended *prior to any commitment to deploy the process* on a site that contains significant quantities of organics that are unconfined in the soil column. . . . feasibility testing is relatively inexpensive [a few thousand dollars]. The focus of the feasibility testing is the performance requirements for the off-gas treatment system and the type and quantity of *secondary waste generated*. Experience with low boiling point organics that are uncontained in the soil column is very limited, and feasibility testing with actual site samples prior to application is strongly recommended" (emphasis added). (V.F. FitzPatrick, "In Situ Vitrification—A Candidate Process for In Situ Destruction of Hazardous Waste," *Proceedings of the 7th Conference on the Management of Uncontrolled Hazardous Waste Sites*, December 1986, pp. 325-332.)

ISV depends on the effectiveness of the collection and treatment system for released gases to keep undestroyed organic contaminants (or products of incomplete combustion) from entering the environment. This off-gas system is like a separation technology; hazardous residues can be either destroyed or landfilled after carbon adsorption. The greater the volatility of contaminants, the greater their release into the off-gas collection system. At Pristine, many of the contaminants are highly volatile at relatively low temperatures. By the time the soil is melted, therefore, many contaminants have moved.

What happens to organic contaminants in ISV is crucial to understanding its cleanup effectiveness relative to other technologies, such as incineration. A published paper reported on a test of ISV on PCB contaminated soil: "Small quantities of PCBs, furans, and dioxins were detected in the untreated off-gas, but none were detected in the vitrified mass. A few samples directly adjacent to the block contained measurable concentrations up to 0.7 ppm PCBs." (R.R. Battey and J.T. Harrsen, "In Situ Vitrification for Decontamination of Soils Containing PCBs," *Proceedings of the Oak Ridge Model Conference*, February 1987, pp. 233-245.) In another report on the same experiment, the "process destruction was slightly greater than 99.9 percent. The small amount of material released to the off-gas system was effectively removed, yielding an overall system DRE of >99.9999 percent." (V.F. FitzPatrick, "In Situ Vitrification—A Candidate Process for In Situ Destruction of Hazardous Waste," *Proceedings of the 7th Conference on the Management of Uncontrolled Hazardous Waste Sites*, December 1986, pp. 325-332.)

The ROD responsiveness summary said: "with worse case conditions, 97 percent of all organics are destroyed. Most tests indicate that 99 to 99.99 percent destruction is achieved." Another ROD statement is more optimistic about destruction versus removal: "The test results [on PCBs] indicate that the organics are destroyed and not merely collected in the off-gas system." All this information shows that ISV might be very effective but that the issue of total destruction of organics through both thermal treatment and off-gas collection, removal and possible treatment needs clarification. Lateral migration of vaporized organics into adjacent soil or perhaps downward into groundwater is also important and needs detailed resolution for application of ISV to any large, uncontained site.

This last issue has received major attention by Larry Penberthy, who calls it vapor retreat. While Penberthy is a competitor of ISV, he makes a good technical arguement: "Instead of being destroyed, the vaporizable chemical contaminants simply move away from the hot core melt by Vapor Retreat, unaltered. They move downwardly below the melt core as well as horizontally away from the melt core. This vaporizing/condensing action is progressive, building up concentration in the isotherm layers corresponding to each chemical's boiling point. This writer expects the DRE to be only 25-50 percent." (Larry Penberthy, letter to Laura A. Ringenbach, attorney for responsible parties, Mar. 28, 1988; Pyro 32A and 32 newsletter of Penberthy Electromelt International, Inc., Apr. 7 and 13, 1988.) This vapor retreat phenomenon could lead to increased contamination of groundwater. Moreover, in order to test for this effect it would be necessary to test a rather large volume of soil so that temperatures away from the molten zone are low enough to have condensation of vaporized contaminants. However, most testing is done on too small a volume of contained material to see this effect.

Penberthy has a number of other criticisms of the tests performed by Battelle which, even after examination of Battelle's comments on Penberthy's analysis, seem important enough to require additional study and testing. Moreover, Penberthy has raised important safety questions, such as effects from soil heating and subsidence, about using ISV at such a heavily industrialized area as the one around Pristine. No significant examination of the risks posed by ISV has been made.

The ROD did not focus on the depth of ISV. The plan is to go down to 8 feet for half the site and 12 feet for the other half. The Battey and Harrsen article (see above) noted that the greatest efficiencies for ISV occur when it is used to depths of 10 to 20 feet. The technology does not work well when contaminants are on the surface and therefore, soil covers are sometimes used. The ROD also noted: "The equipment must be specially designed and produced." The depth and equipment issues are possible causes of underestimated costs.

The other big issue for the Pristine site is the rejection of onsite incineration. The ROD acknowledged: "incineration is a proven technology." "Incineration . . . is fully protective of human health and the environment since the ingestion and leachability threats are eliminated." The ROD did not acknowledge that some stabilization of the incinerator residues might be necessary because of toxic metal contaminants. But overall, the ROD did not note any disadvantages of incineration: "The use of mobile incinerators is common and the performance of these systems has been demonstrated. It is relatively easy to operate the system although a trained operator will be needed."

Nevertheless, incineration was not selected. The ROD said: "vitrification is the lower cost alternative. Therefore, incineration is not recommended for implementation at the Pristine, Inc. site." However, the costing for incineration seems too high. The ROD's total cost estimate of $51 million for incineration was based on a unit direct cost of $730 per cubic yard (for 37,700 cubic yards). Meanwhile, the FS said that the unit cost ranges from $350 to $500 per cubic yard. Several other recent FSs (for the Davis Liquid Waste and Re-Solve sites) by the same RIFS contractor provided detailed vendor costs and analysis for onsite incineration. From those two FSs, OTA used the cost data for three different technologies for a range of contaminated soil to be treated (4,300 to 57,000 cubic yards) and obtained a (conservative) estimate of a unit cost of about $300 per cubic yard for the level of effort at Pristine. This range is consistent information that other vendors gave to OTA.

EPA said recently that mobile infrared incineration of contaminated soils costs "from $120 to $225 per ton [which could be as high as $180 to $340 per cubic yard], depending on the number of tons incinerated per day." (U.S. Environmental Protection Agency, memorandum from John H. Skinner, Office of Research & Development, Dec. 10, 1987.) The FS for Seymour Recycling gave costs for onsite incineration over a very broad range of amounts of contaminated soil: for 35,000 cubic yards the cost was $186 per cubic yard; at the smallest scale (18,000 cubic yards) the unit cost was $349 per cubic yard. In the Crystal City FS the unit cost for onsite incineration was $240 per cubic yard for about half the amount of material at Pristine. In a recent decision for a Superfund removal action at the Southern Crop Services site in Florida, where mobile incineration was selected, EPA said that it expected bids at from $300 to $500 per cubic yard for less than 5,000 cubic yards of soil.

Actual (bid) costs for incineration can vary but do not explain the high estimate used for Pristine. A recent report showed a cost of about $750 per cubic yard (comparable to the Pristine ROD estimate) for a cleanup, but the soil quantity was under 10,000 tons and there was more than just soil to clean. (J.F. Frank et al., "Use of Mobile Incineration to Remediate the Lenz Oil Site," paper presented at *Superfund '87*, 1987, pp. 459-464.) At another site, a vendor (a subsidiary of the Pristine FS subcontractor) got $250 per ton under a turnkey arrangement; total costs probably were about $450 per cubic yard for cleaning between 7,500 and 10,000 tons of PCB contaminated soil. (J.W. Noland, remarks at *Weston Environmental Forum*, Washington, DC, February 1988.) Mobile incineration was used to incinerate materials at the Nyanza Superfund site in Massachusetts. The vendor charged about $600 per cubic yard for a very small quantity, about 200 cubic yards. At the Prentiss Creosote Superfund site in Mississippi, a vendor charged about $200 per ton ($300 per cubic yard) for mobile incineration of 7,500 tons; at the Southern Crop Services Superfund site in Florida, the vendor charged $360 per ton for 3,000 tons.

The Pristine ROD cites no technical factors to explain a $730 per cubic yard cost the site. For example, no mention has been made of buried drums. Even if the ash were to be chemically stabilized because of toxic metal content, the additional cost would not account for the cost descrepancies noted above. Moreover, in an internal inconsistency the FS calculation for a cleanup of only 8,100 cubic yards used a unit cost of $658 per cubic yard; instead of the expected higher unit cost for a smaller volume, a lower figure was used.

In the groundwater cleanup, the ultimate disposition of the collected hazardous substances is uncertain because it is not clear how the carbon that becomes contaminated by removing organic substances will be managed. The ROD said: "Bench scale studies will be done to determine the need for metals treatment." Air stripping only removes volatile organics and carbon adsorption is not likely to be effective for the metals. Maximum reported values of lead in groundwater are 178 ppb and 148 ppb in the upper and lower aquifers; the drinking water Maximum Contaminant Level (MCL) for lead is 50 ppb and the proposed MCL Goal is 20 ppb. For cadmium the corresponding groundwater levels are 39 ppb and 9.4 ppb and the standards are 10 ppb and 5 ppb. The complexity and intensity of groundwater contamination are great enough to warrant more detailed analysis of groundwater treatment, as was done for the Operating Industries site in California.

Any cleanup of contaminated surface water at Pristine is left uncertain by the ROD.

2) Accurate assessment of land disposal and containment alternatives.—The ROD contained an excellent rationale for not leaving contaminated material onsite: "It may leach into the groundwater at levels that will exceed ARAR's [regulatory standards] at some future time and thus increase the groundwater treatment time or require additional future remedial action. The lifetime of a RCRA multilayer cap is finite, and the contaminated soils will be left in place to contribute to groundwater contamination at some future time should the cap fail." The responsiveness summary said: "there are no data available on the long term effectiveness and permanence of RCRA caps."

By its very nature, ISV leaves treated contaminated material onsite. The ROD acknowledged uncertainties about ISV:

- "Vitrification *is expected to be effective* on the soil type present . . . " (emphasis added).
- "Air monitoring will be conducted to ensure that the hood is collecting and treating the gases." (Such monitoring is not routine when mobile incinerators are used.)
- "Some limited monitoring of the vitrified mass will be required to assure that it is a reliable and permanent remedy." (Such monitoring is not routine when stabilization is used.)
- "[There is] limited demonstrated performance. 99.9999 percent DRE [destruction removal efficiency] are expected for dioxin and PCBs."
- "Because this is not a proven technology, prior to implementation of this remedial action, bench and/or engineering pilot scale studies will be required to confirm the effectiveness and applicability of this technology to site conditions."
- "If this treatment method is found to be ineffective, this Record of Decision may need to be reopened."
- "Monitoring will be conducted during the treatment process to determine if contamination is migrating through the soil as a result of the treatment." (Such monitoring is not routine with in situ techniques.)

ISV is not easy to implement—at least, the technology costs more—when water content is high. Thus the ROD noted: "Because of concern over the effectiveness of vitrifying the upper outwash lens, consideration will be given, during these bench and/or pilot studies, to whether the lens should be drained prior to vitrification." Also, the responsiveness summary said twice that the site's soil has "high moisture content" when it defended why vacuum extraction of VOCs was not feasible. However, when the selected ISV remedy was defended, the responsiveness summary—four pages later—said "the moisture content . . . is not high." Either high is high, or actual measured values could be used to show it is high for one technology but not too high for the other technology, if that was the case; however, no actual data were used. (This may illustrate a lack of ROD quality control and ROD rushing at the end of a fiscal year quarter.)

To its credit, the Pristine ROD specified: "The Toxicity Characteristic Leaching Procedure (TCLP) is the testing mechanism that should be used to verify the complete treatment. If this treatment method is found to be ineffective, this Record of Decision may need to be reopened." However, a recent technical report said that vitrified contaminated soil performed poorly:

"The vitrified product as evaluated with these standard leaching tests did not perform well. The reason for this is not known. It may be that the nature of the tests may be inappropriate for monolithic, vitrified masses, or vitrification might not be as effective as chemical stabilization for simple metal systems." (J.J. Barich et al., "Soil Stabilization Treatability Study at the Western Processing Superfund Site," paper presented at *Superfund '87* conference, 1987, pp. 198-203.) According to the report, for example, leaching of zinc—over a short period in a standard EPA leach test—was about 10 times greater than for conventional stabilization. The responsiveness summary portrayed much more certainty: "the metals are encapsulated and bound up in the ISV process." The responsiveness summary also said: "ISV has been tested on hazardous waste and has been successful." These two statements contradict the Barich findings.

Battelle has said that the TCLP is technically inappropriate for monolithic waste forms. Their principal concern is that reducing treated material to fine particles—and exposing unbonded contaminants—is based on the false assumption that treated material may not maintain monolithic properties. Does this mean that, if Battelle is successful in making its point about the TCLP, the Pristine ROD will be reopened because the TCLP will not be used to test ISV's effectiveness?

A recent EPA study that examined eight emerging treatment processes for decontamination of PCB contaminated sediments ranked ISV last by using two sophisticated methodologies. The report said: "all the processes except In Situ Vitrification appear to merit further development for this application." (U.S. Environmental Protection Agency, "Report on Decontamination of PCB-Bearing Sediments," October 1987.) While PCB contamination is not the dominant problem at Pristine and sediments pose a special problem for ISV unless they are dewatered, this report is important because almost all previous information on ISV has come from its developer, including a lot of emphasis on tests on PCB material. The Pristine ROD said: "An additional application [of ISV] is being planned by EPA for a PCB contaminated site." In August 1987 it was reported that EPA Region 5 had "conditionally accepted" ISV for an emergency response action for PCB contaminated materials at the Greiner's Lagoon site in Fremont, Ohio. (*Hazardous Waste News*, Aug. 24, 1987.) As of May 1988, OTA was informed by EPA that no date had been set for the test—the actual removal action at the site—and EPA confirmed that this site action would constitute the ISV test for EPA's SITE program. Only if new test data confirm the presence of high concentrations of PCBs will ISV be used at the Greiner's Lagoon site and, even then, probably not before Spring 1989. If the PCBs are low, then another site would probably be selected, delaying the SITE demonstration still more. The Pristine responsiveness summary said that the demonstration will be performed prior to use of ISV at Pristine.

Failure of the vacuum off-gas collection system is possibile and of concern because of the high population density near the site. The responsiveness summary said: "Should this occur, the organics will be rapidly dispersed in the air, allowing for a very low probability of any adverse impacts through inhalation downwind of the site."

ISV received very detailed examination in the FS for the BF Goodrich and AIRCO site in Kentucky, which was completed several months after the Pristine ROD. ISV was not selected at the BF Goodrich/AIRCO site, primarily because its high cost made it not cost-effective. Several of the comments about ISV in that FS (from a different EPA region and contractor) are important relative to the decision to use ISV at Pristine:

- "The effectiveness of off-gas collection and treatment is not known."
- "The complexities of this repetitive process [incremental movement across a site] are not known since it has not been fully demonstrated on a large site."
- "There is very little data available as to whether vitrification is a reliable technology." (Compare this to the Pristine ROD: "results indicate vitrification to be a reliable technology.")

- "The mass could take several years to cool, depending on the size; therefore, a temporary fence should be constructed to prevent physical contact with the cooling material."
- "Implementation of the vitrification process has yet to be demonstrated on a commercial scale . . . It is probable that the frequency of operation and maintenance problems would be higher than for a proven technology. As a result, reliability would be lower than for proven technologies. Emissions during implementation would require extensive control for both VOCs and dust." These concerns are especially relevant to Pristine because of its location in a highly industrialized area.

Similarly, ISV was rejected at several Superfund sites in Colorado in 1987 (Denver Radium Operable Units: Open Space, Card Property, 1000 West Louisiana Properties, and 12th and Quivas Properties). What is especially interesting is that contamination by radioactive materials would seem to be an ideal application of ISV because it was originally developed as a cleanup technology for radioactive materials. However, all three RODs say the same thing: "[ISV] was eliminated during the initial screening because its implementability for this particular application is unproven. [ISV] has not been demonstrated on a large scale of utilized in a highly-populated urban area like that of the Card property." Moreover, in these cases ISV was also rejected because of the possible "escape of radon gas and associated radon decay products." This would seem to also be applicable to escape of trapped gaseous organic contaminants at a site like Pristine, and the concern undermines the belief that monolithic, solidified ISV material offers secure, tight, and permanent encapsulation.

RIFS contractor.—Camp Dresser and McKee (CDM); the cost was at least $500,000. The ROD did not indicate who did the FS, but a copy of the FS shows it was CDM with Roy F. Weston performing the FS as a subcontractor. The ROD said that several figures in the FS were wrong and recalculated figures were used in the ROD. The ROD also said that after the RI was completed "several gaps were identified" and additional work was done which took another year.

State concurrence.—The ROD said that Ohio's letter of concurrence is forthcoming. This suggests that the ROD was rushed to get it out by the end of the fiscal year quarter.

Community acceptance.—"The community and PRPs are generally in agreement with the groundwater extraction and treatment component of the alternative. Some members of the community have fully supported U.S. EPA's recommended alternative, while the PRPs rejected vitrification and have proposed installation of a RCRA cap with soil gas venting. The City of Reading prefers that U.S. EPA fund a less expensive remedial action and give it the remaining funds to build a new municipal treatment plant."

Special comments.—The FS had an initial discussion of the two main treatment alternatives where unit costs and other data were presented. For in situ vitrification the sole technology developer, Battelle Pacific Northwest Laboratories, was acknowledged and was the source of the data. For onsite incineration, the source of information is described as "Firm A." Only rotary kiln incineration is used in the detailed analysis. Because a wholly-owned subsidiary of the FS subcontractor, Roy F. Weston, Inc., does cleanups with a transportable rotary kiln incinerator it seems likely that subsidiary was Firm A.

The ROD acknowledged some uncertainty about the groundwater cleanup: "The extent of contamination from Pristine, Inc., will be determined by additional studies during the remedial design." However, this ROD addressed the final *source control* remedy and should not be expected to be definitive about the groundwater cleanup. The ROD also noted that contamination in the lower aquifer may be the result of "a multi source groundwater contamination problem in the area." According to the ROD, a variety of other types of actions might be used, including RCRA corrective action.

The responsiveness summary had an interesting interpretation of the provision in SARA

Section 121(b)(2) that says that a technology can be selected even if it has not "been achieved in practice" elsewhere. The interpretation was that the provision allows a technology selection without directly applicable data on its effectiveness before the ROD. Legally, this position seems correct because congressional intent was not to prevent full-scale application just because there has been no prior *full-scale* application of a new technology. But traditional engineering practice does not condone choosing or using a technology without supportive site-specific test data. The issue is that ISV has not been tested sufficiently at Pristine nor on large, unconfined contaminated soil not the absence of successful full-scale use of it at a similar site.

The responsiveness summary would have been more useful had it provided the sources of specific comments, which is normally done.

General conclusions.—There are a number of outstanding aspects to the Pristine ROD. The commitment to meeting SARA's preference for permanent treatment technology is excellent. The commitment to an innovative technology is commendable. The risk assessment is exceptionally good, detailed, and well presented. For example, using a 1 in 1 million risk for ingestion and direct contact, the cleanup targets for soil are 3,182 ppb and 15,041 ppb for benzene and trichlorethylene; but, when removing the threat to groundwater from leaching of the contaminated soil was used, the targets for the two chemicals decreased to 116 ppb and 175 ppb to meet drinking water standards.

Unlike most FSs, the Pristine FS presented a preferred alternative that was recommended for implementation. It is OTA's understanding, from speaking to RIFS contractors, that EPA usually directs them not to give a recommended cleanup. Why was ISV so strongly supported for Pristine, especially before the use of it in the removal action planned by Region 5?

As reported in Pristine's responsiveness summary, EPA's selection of ISV got a poor reception, apparently from responsible parties, because of its unproven state, high cost, and preferential handling in the FS and ROD: "Because of its obvious bias in favor of ISV . . . the FS does not properly evaluate all existing relevant technologies . . . " EPA was accused of being "arbitrary and capricious." EPA defended its selection at great length, including a discussion of why vacuum extraction of VOCs, apparently considered a viable alternative by the responsible parties, is not applicable to the site. (The technology was not analyzed in the FS.) However, EPA's discussion did not resolve the questions raised here about ISV, nor did EPA go into any technical depth in discussing vacuum extraction. Extensive work done for the responsible parties indicates that vacuum extraction, which has been selected for cleanups elsewhere, may be feasible and cost-effective at Pristine (see below). To the extent that ISV reduces risk mainly through removal of volatile organic contaminants, it performs functionally like vacuum extraction removal of volatile organics. But vacuum extraction is intrinsically a lower cost technology that uses less capital intensive equipment and energy than does ISV.

The problem is the decisionmaking process and the accuracy of crucial data upon which it is based. As with so many sites, treatability tests for Pristine were postponed to the post-ROD Design Phase even though test data are necessary to fully support the selection of remedy. *This criticism is not directed at the ISV technology itself*, which might eventually work at the site and which *is* an important new cleanup technology. But the wisdom of choosing ISV for the Pristine site remains questionable for several reasons.

Consider the following initial criterion to be complied with for a technology to pass the initial screening in a feasibility study: "There must be a demonstrated history of successful use of the technology in environments similar to the . . . site. All technologies of a research and development nature, and which cannot be reasonably said to be in common use, are rejected." This criterion is from the 1987 ROD for the Northern Engraving Corp. site in Wisconsin *in the same EPA Region as Pristine*. ISV technology could not meet that criterion, nor is the criterion consistent with SARA, but the point here is inconsistency within the Superfund program.

Either EPA's SITE program needs to prove in situ vitrification or the technology should be released from the demonstration program and accepted as proven technology in ROD selections. Without *treatability study results*, the uncertainty about ISV's effectiveness, when coupled with no cost advantage over proven incineration (see below), weakens Pristine's ROD and the government's attempts to get responsible parties to take over the cleanup. Although SARA allows the use of new innovative cleanup technologies, there is little engineering or public support for selecting an unproven technology without supportive data. Data are necessary to substantiate a technology's ability to meet specific cleanup goals, especially when other proven and cost-effective permanent treatment technologies are available. Moreover, in the Pristine FS, treatment technologies other than incineration were eliminated from detailed evaluation with no technical basis. Although the FS and ROD were clearly committed to using a treatment technology, the alternatives became very restricted. Aside from ISV and conventional incineration technology, no consideration was given, for example, to above ground vitrification of excavated soil in a furnace. This technology was said, by its developer (Penberthy Electromelt International, Inc.), to cost $180 per ton ($280 per cubic yard) in direct unit costs; a transportable furnace would take about 500 days to perform the work at Pristine. These figures are competitive with ISV.

Is EPA prepared to alter its decision in the Design Phase if test results are negative? The ROD said that manufacture of the specially designed equipment "will occur concurrently with the remedial design." In other words, a big investment will be made before test results can support the selection.

The cost of the ISV choice may have been under estimated for several reasons discussed earlier (depth of treatment and building special equipment). The range of unit cost for ISV given in the FS is $250 to $350 per cubic yard. The FS used a mid-range value of $290 per cubic yard. If a unit cost of $350 is used, it leads to a total cost of $26 million instead of the ROD estimate of $22 million. (Total costs include burdens and groundwater cleanup.)

The FS contained initial screening costs for the two treatment options: ISV and incineration. At the screening stage, the two costs looked comparable: ISV at $13 million and incineration at $18 million. These figures seem to come from using the upper range of the unit costs given in the FS ($500 for incineration and $350 for ISV, with no burden added). But the ISV cost increased by 70 percent in the final cost calculations in the FS, while the incineration cost increased by 183 percent, with no explanation provided. There is more uncertainty about the cost of the ISV option, however, than about incineration and just the opposite change in cost would have seemed more plausible.

As discussed earlier, the cost of onsite incineration was seriously over estimated and beyond EPA's standard allowable range of +50/−30 percent. (This allowable range, itself, is large enough to invalidate a technology decision based on cost.) The FS did not use the $425 per cubic yard mid-range value from its own incineration data ($350 to $500); data which appears higher than reliable cost estimates. OTA recalculated the cost of the onsite incineration option. Instead of using $730 per cubic yard (which the ROD used to calculate incineration costs), OTA used $300 per cubic yard (see discussion above). Including all the other costs for the incineration alternative, such as groundwater cleanup, as done in the FS, the total cost for the incineration alternative then becomes $23 million (close to ISV's cost). If the cost of the ISV option is also recalculated to reflect the high end of the cost range supplied by the vendor, then its cost is $26 million. The conclusion is: *onsite incineration is not likely to be more expensive than ISV at Pristine.*

In these recalculations the indirect or burden costs (83 percent) are those used in the Pristine FS; however, these are much higher than those in the FSs for the Davis and Re-Solve sites. At Pristine, various contingencies, construction services, and design costs amounted to a burden of 83 percent, while in the Davis and Re-Solve FSs the burden is 35 percent; the latter explicitly included costs for pilot study work, while the figures for Pristine did not. For Crystal City, the burden was 29 percent; for Chemical Control, 56 percent; and for Seymour Recycling, 60 percent. For the BF Goodrich/AIRCO site in Kentucky where ISV received extensive examination, the total overhead on the ISV direct costs was 60 percent (and the unit cost was $275 per cubic yard). The markup at Pristine was substantially higher than the markups in these other recent FSs. That is, both treatment estimates at Pristine would have been lower if a lower burden were used; with 35 percent, used by the same RIFS contractor in other FSs, the cost for ISV becomes $16 million instead of $22 million and the incineration option (at $730 per cubic yard) becomes $38 million instead of $51 million.

Indeed, mobile incineration might be less costly; if the low $186 per cubic yard figure from the Seymour site (which is in agreement with other data given above for recent *actual contracted costs*) is correct and is used for Pristine, with the same high burden rate as the other alternatives, the total cost of the rejected incineration option is about $15 million (instead of the estimated $51 million) versus $22 million for the selected remedy of in situ vitrification. With the lower, more typical burden rate of 35 percent, the incineration option comes to about $11 million (versus $16 million for ISV at the same, lower burden rate). The Seymour site is in the same EPA Region as Pristine. These two sites illustrate that more regional oversight is necessary to catch inconsistencies in data critical to technology selection.

The lower figures for incineration are important in the context of the government obtaining a settlement with the responsible parties; if this estimate proves correct or closer scrutiny and true costs of incineration at Pristine are indeed much lower than the cost of ISV, then incineration becomes the more attractive *cost-effective* permanent remedy. However, onsite incineration is likely to cost more than vacuum extraction of volatile organic contaminants, which the responsible parties favor. But vacuum extraction is a separation technology, and an important issue (as it is for ISV) is what is done with the extracted contaminants. If they are destroyed rather than landfilled after carbon adsoption, the costs increase. Moreover, the diversity of contaminants at Pristine requires careful analysis of vacuum extraction's ability to remove them; it might be able to do so.

Although at Pristine ISV was rated comparable in effectiveness to incineration and better for cost, its implementability is lower than that for incineration because ISV has not been routinely used for chemical waste cleanups. ISV has a higher level of uncertainty with regard to site conditions, and there is a need for site-specific design. Indeed, the FS said, "There is more data to support incineration . . . Of the soil contaminant destruction alternatives, only [incineration] has a demonstrated performance and reliability." Incineration offers considerably more certainty as to effectiveness, reliability, and cost.

Cost aside, incineration is a less risky selection at this time in the absence of treatability study data that could remove uncertainties about ISV for the Pristine site, especially with regard to off-gas collection and treatment, the migration of contaminants into surrounding soil, the degree of destruction of all organic site contaminants, and safety uncertainties for the surrounding community.

There is another uncertainty about the implementation of ISV. Battelle has exclusive rights from the Department of Energy to market ISV for nonradioactive sites. The ROD acknowledged that "ISV is a patented process which requires a license." Other companies who do actual cleanup work are not familiar or experienced with the technology. However, the Pristine responsiveness summary said: "The selection of ISV is not patently unfair since the developer will be licensing firms to carry out the process and the bid process will be competitive." Subsequently, Battelle changed the way it offers the technology such that its availability and, hence, competition may be restricted. Rather than supplying the technology to cleanup companies, which has not proven a successful strategy, Battelle has helped form a new company with startup capital. The new company, the GeoSafe Corp., will seek additional venture capital and will enter the hazardous waste cleanup business directly with ISV; it has the exclusive worldwide rights for this market. No competitive bid process now appears possible.

The ROD omitted any commitment to SARA's requirement for 5-year reviews when hazardous material remains onsite, a requirement which applies in this case because of the stabilization aspect of the technology. For example, the 5-year review was called for in the Chemical Control ROD, which selected in situ stabilization, and at the Tacoma Tar Pits, which selected stabilization.

The Pristine case illustrates how different offices of the same EPA contractor and how different Superfund contractors can use substantially different data. One contractor's office used a cost for incineration for Pristine of about twice what another of the contractor's offices used for the Davis Liquid Waste and Re-Solve sites. A close examination of the calculations for estimated costs at Pristine reveals that a very high indirect or cost burden was used, compared to indirect costs in FSs for several sites. Such cost variations have no technical basis.

Case Study 7
Renora, Inc., Edison Township, New Jersey, EPA Region 2

Capsule OTA findings:—The selected remedy makes use of offsite landfilling for soils contaminated with PCBs. Biological treatment was selected for soils contaminated with diverse organic compounds and toxic metals and for contaminated groundwater, but no treatability study supported its selection.

Key dates:

- Entered Superfund system: 5/1/81
- Preliminary Assessment: 8/1/82
- Site Inspection: 9/1/81 to 8/1/82
- National Priorities List
  —proposed date: 12/1/82
  —final date: 9/1/83
  —site rank: #378 out of 770
- RIFS start and completion: 5/85 to 8/87
- Public comment period before Record of Decision: 8/18/87 to 9/10/87
- Signing of ROD: 9/29/87
- Estimated complete remediation: 1 to 2 years after signing

Total time.—8 years

Brief description of site.—The site "is an approximately one acre parcel of land in an area zoned for light industrial use. The surrounding area is residential with three sensitive uses (a nursery school, senior citizens center, and an apartment complex) within two thousand feet of the site. . . . two residential developments [were] built in close proximity to the site during the period of time the RI/FS was conducted. From 1978 to 1982 Renora Inc., transported and accepted materials containing hazardous substances for transfer, storage, blending and ultimately, disposal through abandonment at the site [in 1982]."

Major contamination/environmental threat.—Evidence of contamination problems started in 1978. In 1985, the Remedial Investigation (RI) said: "Surficial soils (0 to 2 feet) are primarily contaminated with polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs) and to a lesser extent with volatile organic compounds (VOCs), acid extractable compounds (AECs), other base/neutral organic compounds (BNCs) and heavy metals. Shallow groundwater beneath the site is contaminated with low levels of chloroethane, (a volatile organic compound) and heavy metals. Surface water and sediment samples show levels of heavy metals, tetrachloroethene, phenols and pesticides. No evidence of air contamination was found at the site. No buried drums were found at the site."

The RI concluded that the significant pathways of exposure are direct contact and subsequent incidental ingestion by children trespassing the site, future onsite workers, and future site residents.

According to the ROD: " . . . there are no off-site impacts directly attributable to site operations. Therefore, no management of migration measures were selected as part of the overall remedy for any environmental media. Although groundwater does not pose a public health risk, achievement of target treatment/residual levels will result in restoration of groundwater quality to potable water standards."

HRS scores.—groundwater 69.32; surface water 9.4; air 0.00; total 40.44

Removal actions.—The ROD said: "A removal action was initiated in October 1984 and continued through April 1985. During the cleanup, approximately 33,000 gallons of liquid waste and 28,000 gallons of PCB contaminated waste oil along with approximately 500 cubic yards of non-PCB contaminated soils and 560 cubic yards of PCB-contaminated soils were shipped off-site for proper disposal [presumably in a landfill]." The SCAP shows a Federal removal action 10/23/84 to 10/31/84 at a cost of $27,000 and that the responsible parties performed one, 9/28/84 to 4/16/85. Data from the New Jersey Department of Environmental Protection indicates that the responsible parties spent $4 million for their removal action.

Cleanup remedy selected.—The remedy has four key components:

1. " . . . excavation of all PCB-contaminated soils containing concentrations above 5 ppm [parts per million] (approximately 1,100 [cubic yards]) and off-site land fill disposal . . . "
2. ". . . biodegradation of all PAH-contaminated soils containing concentrations above 10 ppm (approximately 4400 [cubic yards]) . . ."
3. " . . . use of groundwater as an irrigation medium for the bioremediation system . . . " [and]
4. " . . . backfilling, grading and revegetation."

The cost of the selected remedy was estimated at $1.4 million.

A number of cleanup alternatives were examined, including containment approaches, treatment of less material, use of incineration instead of landfilling, and conventional groundwater treatment.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The ROD said: "Overall, [the selected remedy] is protective of public health and the environment. An innovative treatment technology would be utilized as a major portion of the remedy. There is *complete* reduction of the toxicity, mobility, and volume of the contamination. The remedy is permanent and would not require long-term management" (emphasis added). More cautiously, the ROD said the remedy "*significantly* reduces the toxicity, mobility and volume of contaminants" (emphasis added). Also: "Upon completion of the remedy future site uses will be unrestricted."

There is no specific technical information in the ROD or Feasibility Study to support the selection of biological treatment for the Renora site. There are no test data, no citations to the technical literature, nor reference to previous use at specific sites. The ROD stated: "A prerequisite to implementation of the bioremediation portion of the alternative is a pre-design treatability study to refine parameters of the operation." There are a large number of contaminants, and many of the organic contaminants and heavy metals are considered difficult to biodegrade. The biological approach is not off-the-shelf cleanup technology, except for a few simpler types of cleanups.

A key issue is the extent of destruction by biotreatment. While it can be easy to get *some* destruction, it can be very difficult to get complete destruction or as much, for example, as required for incineration (99.99 percent destruction). Finding ways to enhance biodegradation for a complex set of chemicals and for recalcitrant contaminants can be difficult. For example, a recent research paper discussed the "degradation of Benzo[a]pyrene and other recalcitrant PAHs" and explained its failed attempt to foster biodegradation by noting that "organic amendments which are readily utilized for carbon and energy are often ineffective in stimulating degradation of recalcitrant organic compounds." (M.P. Coover and R.C. Sims, *Hazardous Waste & Hazardous Materials*, vol. 4, No. 2, 1987, pp. 151-158.)

The current state of technical knowledge and experience does not support the cleanup selection in the absence of site-specific data to prove effectiveness in meeting the cleanup goals. There are substantially different forms of biological treatments, ranging from simple land treatment to the sophisticated use of bioreactors using a variety of additions to promote and sustain biological destruction to desired residual levels of contaminants, but the ROD dealt with the technology only in its simpler, generic terms.

Biodegradation was selected for the French Limited site in Texas, but the ROD emphasized that "biodegradation of PCBs to the criterion (23 ppm) has not been demonstrated." EPA required, therefore, that a secondary stabilization treatment be used on the residue from the biotreatment.

The FS for the Liquid Disposal site in Michigan examined biological treatment in more detail than most studies and did not select it. A chief reason was: "The level of effectiveness of the biodegradation technologies on a nonhomogeneous waste stream is unknown." The study noted that extensive testing would be necessary to prove the technology effective for the site.

Biological treatment was rejected in the Feasibility Study for Crystal City because "[it] is generally ineffective for destroying these wastes as the treatment is not performed in a controlled environment. Several processes are being developed which show potential. However, none of these processes have been developed past the laboratory stage. Therefore, biological treatment has been ruled out." Biodegradation was also rejected in the ROD for the Tower Chemical Superfund site in Florida: "Biodegradation does not address the metals contamination found at the site and would require long term operations before full clean-up is effective. Other technologies, e.g., incineration, would provide equal destruction efficiencies in a shorter time frame."

The Renora ROD said:

- ". . . bioremediation of soils is considered an innovative treatment technology in the field of hazardous waste management."
- "Although available scientific literature indicates implementation of the bioremediation portion of the alternative is feasible; a pre-design treatability study would be required to confirm the operational reliability of the alternative."
- ". . . the bulk of the contaminated soils (approximately 60 percent of the total) which remain are amenable to onsite bioremediation. Available scientific literature and its use in the oil refining industry indicate that the bioremediation aspect of the selected alternative will achieve the target treatment/residual levels."
- "The prospect for long-term reliability of the alternative would be established by the pre-design treatability work and subsequent verification sampling. However, as this remedy is permanent and *substantially* reduces the toxicity, mobility and volume of contamination the likelihood of remedy replacement is low" (emphasis added; compare to different statement above).

The choice of offsite landfilling over incineration was not discussed in detail in a direct way for the alternative selected. Other alternatives which would include more use of incineration, because no bioremediation would be used, were said to "not result in providing any greater protection of public health or the environment that would justify the incremental cost increase."

2) Accurate assessment of land disposal and containment alternatives.—The use of offsite landfilling for the PCB contaminated soil instead of treatment is contrary to the intent of SARA, even though the amount is relatively small. A recent EPA study on PCB cleanup concluded: "Landfilling of such materials, where legal, is a potential source of groundwater contamination, and only a temporary measure at best." (U.S. Environmental Protection Agency, Office of Research & Development, "Bengart & Memel PCB Site Soil Decontamination Project," undated but apparently 1987.) The FS for the Liquid Disposal site in Michigan said: "*However, moving wastes from one site to another does not constitute a permanent remedial action*" (emphasis added). For Renora, there was no discussion of the negative aspects of using offsite landfilling. The Renora ROD looked strictly from the perspective of this site: "Excavation of PCB contaminated soils and offsite landfilling will physically remove hazardous substances, pollutants and contaminants from the site."

RIFS contractor.—The RIFS was paid for by a group of potentially responsible parties and conducted under contract by BCM Eastern Inc.; $250,000; an endangerment assessment was done by Camp Dresser and McKee under contract to EPA.

State concurrence.—The State of New Jersey concurred with the selected remedy.

Community acceptance.—The responsiveness summary gives little information on what the community felt about the selected remedy.

Special comments.—The analysis of cleanup alternatives was somewhat confusing because some options, including the selected one, referred to offsite disposal consisting of either landfilling or incineration. Except for cost, there were no distinctions made within an alternative for the use of landfilling versus incineration. Therefore, the selected alternative might have received overly high evaluations because incineration was included as an option but ultimately not selected.

The ROD contained a good statement on capping: "[it] would not be considered permanent since the toxicity and volume of contaminants in the soil would remain essentially unchanged."

The ROD did not commit to groundwater monitoring after the selected remedy is implemented, which seems relevant, since it says that the groundwater will be restored to a potable condition and since the HRS groundwater score was quite high. However, the responsiveness summary did include a monitoring step in its description of the selected remedy.

General conclusions.—A key issue is the choice of offsite landfilling over offsite incineration for the PCB contaminated soil. A major driving force behind SARA's requirements for permanently effective treatment technologies was the long-term ineffectiveness of moving buried hazardous waste from Superfund cleanup sites to other land disposal sites. This ROD, considering only this site, implied that offsite disposal results in maximum protection. It did not consider the long-term consequences at *another site* of landfilling materials transported from this site. In addition to the two EPA sources already noted, the FS for the Pristine site in Ohio rejected the option of sending contaminated soil to an offsite landfill because " . . . there is potential for the contaminated soil to cause a problem at the off-site facility. . . . the alternative is not permanent and is the least preferred under SARA." The reasons for ruling out offsite incineration of the PCB contaminated soil at Renora were not given.

The Renora remedy also perpetuates a trend started by the major removal action completed at the site in 1985. A viable alternative, as examined in the ROD, was to incinerate the waste instead of landfilling it. Indeed, the ROD contained an important statement on this point in the discussion of the alternative that was selected: "If the excavated PCB contaminated soils are incinerated instead of landfilled, there would be a permanent reduction in the toxicity, mobility and volume of contaminants in soils." The clear implication is that landfilling is not comparable in meeting SARA's requirements. The chief reason for not selecting incineration of the PCB contaminated soils appears to be its greater cost, an additional $4.6 million. The ROD noted: "it is likely that the [potentially responsible parties] will implement the selected remedy." In other words, approval of offsite landfilling by EPA may have facilitated getting an agreement from the responsible parties to clean up the site.

The interest in using innovative treatment technology is commendable, and some biological remedy may, in fact, be found effective. But the ROD decision was made without supporting technical information. The ROD and the FS contained no details about the technology. There are many forms of biological treatment, and it is still too new a cleanup technology to make assumptions on effectiveness at a site with so many organic contaminants, some at relatively high concentration. Technology specificity is high for biological treatment, which means that it is difficult to extrapolate success from one waste to another. Delay of treatability testing until after the ROD creates considerable uncertainty and the potential for actions which are not fully protective of public health and environment because of either substantial loss of time or a compromise of cleanup goals if the testing shows problems in the biotreatment. Indeed, because of the need for extensive treatability testing, the estimated time for complete implementation seems overly optimistic. Such biological treatment (both aerobic and anaerobic processes) of contaminated soil was rejected at an early screening stage in the Pristine FS because "Mixed wastes and low concentrations (less than 100 ppm) are difficult to treat." The same condition exists at Renora.

Because of the use of landfilling and the selection of an unproven treatment technology, the selected remedy cannot be assured to be permanent. Moreover, compliance with SARA's requirement on the reduction in toxicity, mobility, or volume was described in three different ways: complete, substantial, and significant. This puzzling situation may indicate end-of-fiscal-year ROD rushing or confusion over the capabilities of the selected remedy.

Case Study 8
Sand Springs Petrochemical Complex, Tulsa County, Oklahoma, EPA Region 6

Capsule OTA findings.—EPA originally said solidification technology was ineffective for the high organic content site wastes and incineration was effective. Nevertheless, EPA reversed itself and selected solidification for most of the cleanup, which the responsible party had found effective in its treatability study. Incineration is to be used if solidification technology is not successfully demonstrated or fails after solidified material is landfilled on the floodplain site, but the criteria for failure are unspecified.

Key dates:

- Entered Superfund system: 8/1/80
- Preliminary Assessment: 6/1/80
- Site Inspection: 11/1/80
- National Priorities List
  —proposed date: 10/84
  —final date: 6/86
  —site rank: #761 out of 770
- RIFS start and completion: 6/29/84 to 5/4/87
- Public comment period before Record of Decision: 7/29/87 to 9/1/87
- Signing of ROD: 9/29/87
- Estimated complete remediation: 11/91

Total time.—11 years

Brief description of site.—"The site operated as a refinery from the turn of the century through the 1940s. The property has since been developed as an industrial area and consists of an abandoned solvent and waste oil recycler, an active transformer salvage/recycler, active chemical manufacturers and various other industries. . . . the site is located on the northern bank of the Arkansas River, immediately west of Tulsa, Oklahoma. The site encompasses approximately 235 acres [and] includes unlined acid sludge pits, a surface impoundment, surficial sludge contamination, solvent and waste oil lagoons and contaminated sediments. The [site] is located in the alluvial floodplain of the Arkansas River."

Major contamination/environmental threat.—"Total known waste volume is approximately 130,000 cubic yards. During the period of operation hazardous substances were stored or disposed of in drums, tanks, unlined pits and lagoons or buried on-site. These substances include various volatile and non-volatile organics, chlorinated solvents, and sludges containing heavy metals. Waste pits have contaminated local groundwater and caused migration of surface contaminants."

EPA concluded that there are four major sources of risks: direct contact with organic carcinogens and highly acidic wastes and surface waters; air emissions of acid fumes and volatile organic compounds; surface waters polluted by runoff during heavy rains; and groundwater being contaminated directly by lagoons and indirectly from site runoff: "in heavy rains the site is submerged."

According to the FS: "It is believed that contaminants from the pits, ponds, and lagoons are leaching into the alluvial aquifer, therefore, a major pathway for migration is probably groundwater. However, by definition this pathway has been excluded from consideration during the FS for the Operable Unit." The same contamination problem exists for surface water migration offsite. The FS also said: "Several on-site ponds and lagoons have a history of breaching their containment structures: there have been incidents of dike walls breaching for one of the Glen Wynn lagoons, as well as flow of materials from the river acid sludge pits into the Arkansas River, which have occurred in the past . . . . the contents of the large and small acid sludge pits had breached their dike walls on several occasions."

HRS scores.—groundwater,44.90; surface water 21.82; air 0.00; total 28.86

Removal actions.—A private party performed a removal action in 1984; there are no details in the ROD.

Cleanup remedy selected.—EPA designated this cleanup as a source control operable unit that covered surface liquids, sludges, and heavily contaminated solids but not minimally contaminated soil or groundwater. The latter is to be addressed in a subsequent ROD. Originally, before the ROD was officially signed, EPA selected onsite incineration of wastes and solicited public comment on it as part of the RIFS public comment period; the agency had already evaluated solidification and onsite landfill and solvent extraction, all of which were rejected. EPA changed its mind and selected solidification, accepting a five-part proposal by Atlantic Richfield Company (ARCO), a responsible party, that included:

1. excavation and offsite thermal destruction of some unspecified volume of surficial sludges;
2. solidification and/or stabilization of all remaining sludges and containment of the resulting material in an onsite RCRA hazardous waste landfill;
3. demonstration that solidification technology meets EPA approved criteria and, should it not do so, use thermal destruction [apparently onsite];
4. no liability release for the site or from future maintenance and monitoring; and
5. repair or restoration of the landfill to ensure no migration or destruction or treatment of all or a portion of its contents, as EPA deems appropriate, should monitoring show that the solidification/stabilization remedy fails.

It appears that ARCO is anticipated by EPA to sign a consent decree, agreeing to pay for the cleanup.

Cost data on the selected remedy is absent because the combination of solidification and incineration was not evaluated in the FS. It is unclear how much material will be incinerated offsite initially. But if solidification is used it will cost less than incinerating all the waste. Incineration was estimated in the ROD to cost $67 million and complete solidification was estimated at $38 million (the comparable figures in the FS are $54 million and $31 million). OTA estimates that the probable comparable cost of the five-part remedy is $45 million, but this figure is highly uncertain because there are many different forms of solidification.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—EPA said in the ROD that the selected remedy, based mostly on solidification, fulfills the statutory preference. However, as EPA stated: "on-site thermal destruction of wastes . . . appears to meet more statutory selection criteria than the other remedies evaluated." With solidification, "unlike on-site thermal destruction, the toxicity of wastes would not be reduced and the volume of wastes would be increased."

EPA views in the ROD on the chosen solidification option at this site included the following:

- ". . . [there was a] lack of demonstrated permanence."
- ". . . the capability of solidification or stabilization techniques to permanently bind with high organic wastes, such as those found at Sand Springs, has not been demonstrated in the pilot studies conducted on-site."
- ". . . without further treatment free liquid contaminant concentrations were not reduced to meet RCRA land ban restrictions."
- ". . . the unconfined compressive strength of the stabilized material . . . does not meet the recommended disposal criteria."
- ". . . leaching tests conducted by EPAs Cincinnati laboratory show that the solidified material leaches contaminants."
- ". . . leaching of contaminants, and incomplete encapsulation [small globules of waste were seen] raises questions about the long term effectiveness and permanence of the process."
- the waste ". . . contains 50 percent organic compounds raising doubts about the ability of stabilized or solidified waste to meet RCRA requirements in the long term."
- samples ". . . show obvious degradation of the solidifying matrix following analysis for total organic content."
- ". . . the net assessment is that solidification or stabilization processes present difficult problems with respect to meeting ARARs [standards]."
- ". . . possible air emissions."
- ". . . volumetric increase of 50 [to 200 percent]."
- ". . . the potential for failure was determined to be greatest for the on-site solidification remedy."
- ". . . the source of the contamination will not be destroyed."
- additional ". . . studies will need to be performed on the subsurface petroleum wastes."

The FS summed up its evaluation of onsite solidification: "Not a proven technology for high organic waste. Contaminant source isolated, may not be rendered non hazardous. May not meet ARAR." It remains unclear whether the test results supplied by ARCO removed all of the above concerns for EPA; but the inclusion of the third provision in the five-part remedy which requires demonstration of solidification technology suggests that EPA was not fully convinced by the ARCO test data or that it did not have enough time to fully evaluate it prior to signing the ROD.

EPA has tied the environmental acceptability of the solidification remedy to two conditions: "if the effectiveness of this concept is adequately assured or if ARCO undertakes the corrective actions deemed appropriate by EPA should the remedy fail." No such conditions would have been attached to the originally chosen thermal destruction remedy, which ARCO also examined in its treatability study and which was found to work effectively. Cause for EPA rejecting the incineration option in the ROD was said to be its "serious implementation problems," but EPA's FS analysis also said that all the processes that would treat waste onsite "are judged to each have the same degree of implementability." Moreover, the ROD stated: "Actual implementation time for solidification and thermal destruction is comparable . . . "

EPA said: "The proposed remedy is considered permanent." And that it "is cost-effective compared to equally environmentally protective alternatives." But EPA also said that the thermal destruction alternative offered more overall protection than solidification. The FS summed up its case for onsite incineration: "Proven technology destroys hazardous material. Containment source worker health and safety addressed in remediation. Meets ARAR."

2) Accurate assessment of land disposal and containment alternatives.—With regard to future operation and maintenance, the ROD said that these "will be minimized since the source of the contamination will be removed." But, as the ROD also stated, solidification does not destroy the source of contamination that *will* be left onsite. The ROD contained a replacement cost of $100 million should failure occur for the onsite solidification and landfilling option but no cost for the incineration alternative. For these two pure (single technology) options, the reduction in cost of about $30 million for solidification is offset by a possible future re-remediation cost of $100 million. And, that tradeoff still exists.

The onsite landfill is supposed "to reduce groundwater infiltration and the chances of any contaminants migrating off-site." But if " . . . significant, unforeseen, off-site migration or contamination occurs as a result of the site, appropriate remedial measures will be taken." No detailed analysis of future failures was given. The ROD did not express concern about having the onsite landfill in a location that is submerged in heavy rain and that is in a floodplain adjacent to the river. The ROD stated further: "While a hazardous waste landfill of solidified waste would protect health in the short term, the long term stability of this material is not proven."

For Sand Springs, the importance of the water level to remedy selection is striking. The ROD for the Tower Chemical Superfund site in Florida, for instance, commented on the use of chemical stabilization followed by onsite land disposal, a remedy the ROD rejected. The comments apply directly to the Sand Springs site: "Although this process is effective in addressing inorganic contamination, the volume of materials would increase, thus causing increased disposal facility requirements. In addition, the soils being solidified contain significant amounts of organic compounds which could affect the integrity of the cement monolith. The presence of organics will require containment of the monolith within an on-site landfill built above the land surface due to the locally high water table. This technology would also require long-term (30 years) monitoring which is less favorable than technologies which provide permanent destruction of wastes . . . a high water table at the site makes it infeasible to solidify or build an on-site landfill which meets the design specifications outlined in RCRA."

The issue of effectiveness of solidification technology for organics is critical for Sand Springs. The FS for the Re-Solve site in Massachusetts rejected stabilization because "there has been limited success in chemically fixing organic contaminants such as solvents and PCBs." The ROD for the Liquid Disposal site in Michigan, which also selected stabilization for soil contaminated with organic chemicals, said that the hazardous substances "will not be permanently destroyed" and "hazardous chemicals still remain in that [treated] mass." And the FS for the site said: "Considerable research data exists demonstrating the effectiveness of this technology in immobilizing a wide range of contaminants, primarily inorganics. A substantial amount of data does not exist, however, to accurately judge the long-term reliability of the process. Long-term leaching and volatilization can be expected for soluble and volatile organic wastes." Although, stabilization was selected for Liquid Disposal, so was the use of a slurry wall and impermeable cap around and over the treated material, as a second level of control. The ROD for the French Limited site in Texas (same EPA region as Sands Spring) said: "Fixation is questionable due to high organic content of untreated soils."

An EPA report's observations on halogenated organic wastes also apply to the selection of chemical stabilization for Sand Springs: "the area of solidification/encapsulation is one requiring additional study before it can be considered viable technology." (U.S. Environmental Protection Agency, *Technical Resource Document: Treatment Technologies for Halogenated Organic Containing Wastes*, vol. 1, January 1988.)

Another EPA document, used to teach cleanup workers about waste treatment says: "Solidification technologies are designed to be used for final waste treatment. This means the technology should be applied only after other treatment techniques have been applied, i.e., incineration, chemical treatment or other." (U.S. Environmental Protection Agency, "RCRA/CERCLA Treatment Alternatives for Hazardous Wastes," October 1987.)

A specific type of solidification tested for Sand Springs was mentioned in the FS for Crystal City, but the solidification/landfill alternative was not selected at Crystal City. Data provided by the vendor, on waste from some other site, and reported in the Crystal City FS on two contaminants also present at Sand Springs (2-methylnaphthalene and phenanthrene) showed high levels in the leachate. A demonstration of the same stabilization technology under EPA auspices concluded: "for the organics, the leachate concentrations were approximately equal for the treated and untreated soils." (P.R. de Percin and S. Sawyer, "SITE Demonstration of Hazcon Solidification/Stabilization Process," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.)

A recent EPA study found "large losses of organics during the mixing process." (L. Weitzman et al., "Evaluation of Solidification/Stabilization As A Best Demonstrated Available Technology," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.) Another EPA study showed that stabilization was not competitive with thermal and chemical treatment technologies and soil washing for organic contamination. (R.C. Thurnau and M.P. Esposito, "TCLP As A Measure of Treatment Effectiveness: Results of TCLP Work Completed on Different Treatment Technologies for CERCLA Soils," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.)

RIFS contractor.—State led; $1.1 million; John Mathes & Assoc.

State concurrence.—The State of Oklahoma favored solidification over incineration.

Community acceptance.—EPA judged that the community was more in favor of solidification than incineration. The community was very concerned about the future use of an incinerator for waste from other sites, the worsening of the area's air pollution, and harm to the local economy. (Building an incinerator for industrial waste is frequently sold by industry to communities as a local economic advantage; several efforts to site a hazardous waste incinerator in Oklahoma are underway.) Although EPA tried to allay the community's concerns about incineration, ultimately the community preferred the uncertainties of the solidification technology and accepted the assurances that incineration would be used if solidification was less effective.

On this issue of the safety of mobile incineration, Sand Springs can be compared to the Davis Liquid Waste site in Rhode Island where there also was substantial, documented community concern about onsite incineration, concern to which EPA responded with good technical points but, unlike Sand Springs, did not alter its choice of incineration. Also, in the ROD for the French Limited site (in the same EPA region as Sand Springs), EPA defended mobile incineration: "Performance standards for air emissions from incinerators would be met, minimizing the risk from these emissions. EPA considers the implementation of an incinerator to be relatively simple in comparison to the other alternatives evaluated in the summary."

Moreover, it is not clear that the community was totally aware of air pollution problems with solidification. EPA's responsiveness summary said: "Pilot studies have shown that some volatile compounds are driven off during excavation and mixing of the waste with the solidifying agent. Mass emission rates have not been quantified."

Special comments.—The ROD's analysis of cleanup alternatives said that for any alternative it will be necessary to pump and treat surface impoundment liquids and to discharge them into the Arkansas River; no details were given. Moreover, the accepted ARCO proposal made no mention of these needs.

General conclusions.—Sand Springs has some good points: 1) pilot treatability studies were used to evaluate treatment technologies; 2) alternative treatment remedies were analyzed; 3) EPA responded to the concerns and interests of responsible parties, the community, and the State; and 4) some preferred treatment technology was selected by EPA.

But Sand Springs has many problems too, including a lot of confusion about what test data were used by EPA and when. The ROD selected not a reliable permanent remedy but a plan with several contingencies, with no assurance of a permanent remedy. Over a short period of time —about one month—EPA reversed a well-supported, technically sound decision to use incineration rather than solidification/stabilization technology. In the ROD, EPA said: "Solidification was considered in detail during the Feasibility Study and actual pilot studies. Adequate information is available on which to base a decision." Was EPA talking about the information available when it signed the ROD, including the ARCO test results, or information obtained by EPA prior to the RIFS public comment period? The ROD suggested that EPA had conducted its own tests on solidification of site materials. But it may have used a very different type of solidification technology. In the ROD responsiveness summary EPA said: "The [ARCO] pilot studies had a major influence on the remedy selected." If that was so, then why did the ROD still contain so many negative comments about solidification? Part of the answer may be revealed in another statement by EPA in the ROD's responsiveness summary: "Solidification pilot tests [presumably ARCO's] were only conducted on the surficial acid sludge waste. Additional waste characterization and pretreatment studies will need to be performed on the subsurface petroleum wastes." Another part of the answer is that EPA had *conflicting* test data from two different sources on several solidification technologies. Therefore the question persists: Was there enough test data to justify the ROD's selection of remedy?

The ROD contained no details on how EPA will assure that independent, detailed, and timely testing will track progress on the selected remedy and detect ineffective performance in the long term, if that occurs. If the treatment technology is ineffective, contaminants will leach out of the solidified mass, because the treated material will be placed into a landfill on a floodplain adjacent to the Arkansas River. Landfill failure was not considered, nor is its location compatible with regulated use of land disposal. Moreover, cause for concern about independent testing and verification of solidification's effectiveness is driven by ARCO's position that *any* form of waste treatment is unnecessary: "Improved site security and a clay cap would mitigate this [accidental direct contact] potential risk." (ARCO, letter to Carl Edlund, EPA Region 6, Aug. 31, 1987.) ARCO's critique of EPA's FS of August 31, 1987, said that fencing and a cap "could be a sufficient remedy." Moreover, in this document ARCO also said: "Long term effectiveness of incineration, stabilization and solidification are comparable." These views of ARCO suggest that the selection of solidification, with costs much lower than incineration, was a compromise made by both EPA and ARCO and that future, post-ROD actions require close EPA scrutiny.

ARCO's effort to get EPA to retrench from its original decision to use incineration probably was helped by its apparently successful criticism of the quality of the RIFS. Indeed, a number of ARCO's comments are consistent with OTA's observations in this report for RIFSs in general. For example, ARCO said: 1) "significant gaps exist in the data presented and considered in the FS"; 2) "The analysis reflected by the FS is cursory and of limited detail"; 3) "The lack of back-up, the limited detail and the lack of references suggested that the analysis may not have involved the development of any additional information beyond that provided by the authors' experience"; and 4) "The FS is characterized by an over-reliance on assumptions rather than actual performance data."

A big question still remains. Who bears the burden of proof that a treatment technology works before EPA officially endorses its use at an actual cleanup? There is no basis in the technical literature for concluding that solidification/stabilization technology is likely to be effective for wastes with so much and so many different kinds of organic contamination. The presence of negative laboratory results, which

EPA suggested it had prior to the ARCO test data, would normally prevent application of a cleanup technology at the site in question. It is true that unusual conditions might justify an unproven technology; for example, in an emergency situation and where all other treatment technologies are less applicable. But this site is not generally considered to require emergency attention, and the pilot study on incineration was successful. (Note that stabilization of incinerator residue contaminated with metals only is proven technology.) It may well be that, as EPA says, the technology proposed by ARCO is "a promising innovative technology," but sanctioning its full-scale application through a ROD on the basis of limited data obtained by the responsible party that conflicts with data obtained by the government, is a big step, especially because the data are inconsistent with what is generally understood about the capabilities of the technology. In fact, there are a number of very different proprietary forms of solidification and stabilization (ARCO actually tested two and got similar results), and it is not clear that either ARCO or EPA has considered or evaluated enough of them and their performance relative to the technologies used in the ARCO treatability study.

The degree to which the ARCO data support EPA's decision also raises the issue of how accurately current EPA tests—in this case for hazardous waste treated by stabilization—predict long-term environmental effectiveness. Much more rigorous testing appears necessary to make the case that stabilization of hazardous *organic* material, such as at Sand Springs, assures insignificant leaching of organic contaminants under long-term conditions at the site. Therefore, although the ARCO test data do look good, they are limited by the test procedures themselves. Nor were the ARCO test data obtained by using standard test protocols and quality assurance procedures to assure the public and the government that the data are reliable. Doing this is a major effort and an important characteristic of EPA SITE program and most treatability testing done by or for the government.

After the ROD was issued, a news publication reported: "Solidification poses 'very little risk whatsoever,' says an EPA headquarters source, who is encouraged that the agency is willing to allow its use at a Superfund site. The technology has not been proven to 'truly bind organics,' but any release of organic substances would be slight, the source explains." (*Inside EPA*, Nov. 27, 1987, p. 13.)

Moreover, the solidification technology evaluated by ARCO appears to be one which is in EPA's SITE technology demonstration program to "resolve issues standing in the way of actual full-scale application." The demonstration was conducted October 13-16, 1987, at the Douglassville Disposal Superfund site in Pennsylvania, but results of the test were not made available before the ROD and EPA made no reference to them for Sand Springs. Results recently made available were negative for organic contaminants.

The way the remedy selection was made illustrates what can happen when there is much pressure to issue a ROD by the end of the fiscal year. ARCO submitted its treatability study results to EPA on July 15, 1987. As late as August 21, 1987, results from ARCO's pilot tests were still being obtained and disseminated among EPA staff. Several formal ARCO reports are dated August 31, 1987, including one criticizing EPA's RIFS. This site, like a very high percentage of all Superfund sites, had its ROD issued in the last days of the fiscal year (September). In this case, EPA might have stayed with its original, technically supported decision and kept on schedule or delayed issuing the ROD while it: 1) designed more tests for ARCO to carry out to convincingly demonstrate, before actual use, the long-term effectiveness of solidification/stabilization technology for the diverse wastes at the site; and 2) developed detailed protocols for future testing and monitoring as well as technical criteria which would trigger the switch to incineration, if solidification failed. In this case, the responsiveness of EPA to local pressures seems to be related to selecting a lower cost technology and facilitating the government's attempts to have a private party fund the cleanup.

As with the Compass Industries Superfund site directly across the Arkansas River from Sand Springs, little attention was given to possible groundwater contamination from the remedial action for the present hazardous material and to the risks to downstream water users from cumulative discharges into the river.

Case Study 9
Schmalz Dump Site, Harrison, Wisconsin, EPA Region 5

Capsule OTA findings.—A simple compacted earth cover over the soil contaminated with lead and chromium was selected. Solidification/stabilization treatment was rejected, although this was a textbook example of appropriate use of the technology. Voluntary well abandonment and monitoring was chosen over pumping and treating contaminated groundwater.

Key dates:

- Entered Superfund system: 5/1/83
- Preliminary Assessment: 5/23/83; (5/1/83 in CERCLIS)
- Site Inspection: 5/23/83; (5/1/83 in CERCLIS)
- National Priorities List
  - —proposed date: 9/1/83
  - —final date: 9/1/84
  - —site rank: #190 out of 770
- RIFS start and completion: 12/28/84 to 8/14/87
- Public comment period before Record of Decision: 8/17/87 to 9/8/87
- Signing of ROD: 9/30/87
- Estimated complete remediation: 20 months (around 6/89)

Total time.—6 years

Brief description of site.—The ROD said: "The Schmalz Dump Site is located on the north shore of Lake Winnebago in the Town of Harrison. The site occupies approximately 7 acres in the Waverly Beach Wetlands area. The neighboring city of Appleton, with a population of 60,000, has its drinking water intake approximately 1200 feet from the shore of Lake Winnebago, in close proximity to the site." Various types of waste were disposed there from 1968 to 1979.

Major contamination/environmental threat.—According to the ROD, there was "Initial on-site sampling by the State of Wisconsin and the U.S. Army Corps of Engineers in early 1979 . . . Lead and chromium were also detected in relatively high concentrations at several sampling stations. Lead and trivalent chromium [the least toxic form of chromium] were found throughout [soils at] the site at concentrations ranging from detection limits to 1940 milligrams per kilogram (mg/kg) and 964 mg/kg respectively . . . . lead and [trivalent] chromium in soils . . . with concentrations greater than 14 mg/kg and 100 mg/kg respectively, pose an unacceptable lifetime risk from direct contact." The ROD indicated a volume of contaminated material of 8,000 cubic yards.

The second environmental threat was contaminated groundwater. " . . . the silty sand aquifer beneath the site appears to be separated from the lower aquifer by a fairly thick, continuous clay layer. It is therefore unlikely that contaminants from the site would enter the lower aquifer and reach residential wells. The shallow aquifer beneath the site contains levels of trivalent chromium above background but not above the MCL [Maximum Contaminant Level]. . . . the water table is three to five feet below the land surface and direction of flow is . . . towards Lake Winnebago." Regarding the ability of lead and chromium to leach from the soil, the ROD said: "Results of the tests show that very low levels of both lead and chromium are leachable. . . . trivalent chromium has an affinity to fine grained, silty soils like those found in the site area." A groundwater modeling study "indicates that in fifty years, groundwater containing chromium would have migrated just beyond the site boundary."

A complex technical issue for this site is that there are two different chemical forms of chromium: the more toxic hexavalent form and the less toxic trivalent form. The analysis for soil contamination recognized that even trivalent chromium is toxic. However, the analysis of the groundwater threat discounted the hazard from trivalent chromium or from it turning into hexavalent chromium.

HRS scores.—groundwater 27.62; surface water 80.00; air 0.00; total 48.92

Removal actions.—Earlier operable unit cleanup involved removal of PCB contaminated materials in 1987; Remedial Design, $81,000 and Remedial Action, $2.6 million.

Cleanup remedy selected.—This ROD is the second one for the site. The first ROD in August 1985 addressed PCB contamination at the site and selected "removal of construction debris and sediments containing elevated concentrations of PCBs."

Alternatives examined included: 1) groundwater pumping with treatment, slurry wall and cap; 2) a RCRA cap; and 3) solidification/stabilization treatment of soil and onsite disposal of residues. The ROD said: "The preferred alternative involves the installation of a low permeability, compacted earth material cap over approximately seven acres of lead and chromium contaminated soils, and implementation of groundwater monitoring for lead and chromium. A voluntary well abandonment program for nearby wells is also proposed."

Estimated costs for the groundwater treatment alternative were $3.4 million; for solidification and/or stabilization, $2.8 million; for a RCRA cap, $2.4 million; and for the selected remedy of a soil cover $800,000. (In the body of the ROD the selected remedy is called a *soil cover*, but in the beginning of the ROD it is called a *cap*. Soil cover is more accurate because a cap implies a more complex, engineered approach to containing hazardous waste.)

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The Schmalz ROD was straightforward: "The statutory preference for treatment set forth in . . . SARA is not satisfied because treatment was found to be impracticable due to questionable technical feasibility, inadequate short-term protection, and inappropriate site conditions." With regard to overall environmental protection, the ROD said the selected remedy "would provide adequate protection from contaminated soils on site." Treatment was rejected for both contaminated groundwater and soil. The ROD noted for both treatment approaches: "Treatability or compatibility testing is required . . . prior to design and construction."

EPA has said, however: "Toxic metals represent a long term threat in the soil environment. This threat can be reduced considerably if the heavy metals can be permanently immobilized by either chemical or physical methods." (U.S. Environmental Protection Agency, *Review of In-Place Treatment Techniques for Contaminated Surface Soils*, vol. 2, November 1984.)

The ROD acknowledged that solidification/stabilization of excavated soil could be "a permanent remedial action to limit the off-site mobility, solubility [an unusual term instead of volume] and toxicity of the heavy metals." The selected remedy "is expected to significantly reduce the mobility of lead and chromium by containment in the site soils, but do nothing to reduce toxicity or volume of contaminants." The chief reasons for rejecting solidification/stabilization were that:

- Excavation is risky "due to potential airborne migration of dusts from the site."
- "The reliability . . . is unknown principally due to the lack of data documenting long-term success or failure of similar projects."
- It " . . . is not expected to significantly minimize risks associated with ingestion of soils without additional restrictions on use of the site (e.g., additional fencing)."
- " . . . there is considerable research data to suggest that silicates used together with a cement setting agent can stabilize a wide range of materials including metals. However, the feasibility of using silicates for any application must be determined on a site specific basis, particularly in view of the large number of additives and different sources of silicates which may be used." (Interestingly, the paragraph is verbatim from the book *Hazardous Waste Treatment Technologies*, by Gerald Rich and Kenneth

Cherry, 1987; the statement is a good explanation of the need for a treatability study for solidification.)

- "Based on the content of soils on the site . . . [the alternative] may be difficult to implement. Contaminated soils consist of solid waste, wood, brick, and car bodies, which would make implementation difficult."
- its " . . . reliability . . . is unknown."
- it " . . . is not conducive to a wetlands environment. Capping and vegetation of the site is."

With the groundwater problem, there are two subtle issues. First, the ROD emphasized the sampling data for chromium concentration in the shallow aquifer, which ranged from 14 to 48 micrograms per liter (μg/l) and the fact that the values are below the MCL of 50 μg/l. However, the highest value is close enough to the MCL value to worry about the precision of sampling and the possibility of future increases in concentration. Indeed, EPA work indicates that chromium can be under reported by more than enough to make the 48 μg/l observation above the standard. (K.A. Aleckson et al., "Inorganic Analytical Methods Performance and Quality Control Considerations," *Quality Control in Remedial Site Investigation*, American Society for Testing and Materials, 1986, pp. 112-123.) The ROD said: "Groundwater was determined not to be a public threat because chromium concentrations are below [Safe Drinking Water Act] drinking water standards. However, leaching of chromium and/or lead to groundwater could potentially cause drinking water standards to be exceeded. Based on the above discussions [of small amount of leaching according to standard tests and affinity to soil], onsite soils are not likely to ever increase chromium and lead concentrations in the ground water to greater than the drinking water MCLs of 50 μg/l. However, because there is a remote possibility that this pathway could later become a concern, it was determined that groundwater should be monitored over time. In addition, residents in the vicinity of the site will be asked to voluntarily abandon any existing wells. This is a precautionary measure to ensure that no potential for exposure exists should contaminant levels in groundwater increase in the future."

The ROD's case is supported by the results of leachability tests which found low levels of both lead and chromium; however, the test employed does not necessarily describe long-term effects under actual site conditions. The ROD also noted that the background groundwater level for chromium is 5 μg/l; therefore, there is contamination from the site. However, the ROD also said: "groundwater contamination is not above MCLs and there is no leachate release."

The ROD for the Tower Chemical Superfund site in Florida, where there is chromium contamination in the groundwater, had a target cleanup level for the treatment of 100 million gallons of water of 0.05 μg/l even though the groundwater standard is 50 μg/l. The public health threat there is considered minimal.

The second groundwater issue is a second plume of contamination which the ROD described as "an isolated off-site anomaly west of the Schmalz Site." Two concentrations reported for the location are 185 μg/l and 1140 μg/l of dissolved chromium. The contamination "appears to emanate from a localized point source. Based on the history of dumping in the area, this phenomenon is not unusual." It seems that a narrow definition of the site boundary kept these higher concentrations from being considered a significant factor in selecting the cleanup remedy. Information in the ROD clearly indicates that the second plume would also flow into Lake Winnebago.

Overall, the critical ROD conclusion was: "Based on the rate of groundwater movement, and taking into consideration the dilution that would occur once ground water discharges to the Lake, the levels of chromium in the groundwater should never pose a threat to Appleton's water supply." Groundwater treatment was also rejected because "several problems can occur at each component stage. This could result in delays or inability to implement the alternative."

In summing up its comparison of alternatives, EPA said that groundwater treatment "does not protect against direct contact" and that the solidification/stabilization treatment of the soil "would be protective upon implementation, however, there are several problems associated with implementation of this alternative that make it undesirable." The use of a slurry wall and cap or a RCRA cap are "not cost effective because they provide excess protection for groundwater."

2) Accurate assessment of land disposal and containment alternatives.—The word permanent was not used to describe the overall selected remedy. The ROD said that the cap is protective and that the groundwater monitoring "will provide protection from potential future releases."

Regarding permanency of the selected remedy, the ROD said that " . . . the only potential need for replacement is seen to be that of the cap or soil cover. This need could occur if the original cap was washed out by some storm event, if heavy equipment were to abrade the cover, or if unforeseen subsidence were to occur." No restrictions on future land use were set, and the ROD noted that EPA has legal authority "to issue an order for corrective action, should the owner make an attempt to damage the cap." A letter from the State said, "the cap could be damaged by the landowner, who has indicated a desire to build on the site." The ROD for the Tower Chemical site in Florida eliminated the alternative of using a soil mixture cap because: "*This technology is unproven and has extensive monitoring requirements. Development of dessication cracks could cause failure. High failure potential*" (emphasis added).

In the FS for the French Limited site (in EPA Region 6), use of a slurry wall and cap to contain hazardous waste was described as a "temporary solution" for which the "volume and toxicity would not be affected . . . [and] . . . the potential would always exist for failure of either the cap or the slurry wall allowing for the movement of unstabilized wastes contained onsite."

The decision not to use a RCRA cap was inconsistent with statutory requirements about satisfying current regulations, and it raises significant uncertainties about future failure. Official EPA guidance notes: "A key task of cover design is the selection of suitable materials. The cover usually will include a synthetic membrane and a large volume of soil or soil-like material . . . " (U.S. Environmental Protection Agency, "Project Summary—Design, Construction, and Maintenance of Cover Systems for Hazardous Waste: An Engineering Guidance Document," November 1987.) The selected cover is very simple and poses substantial uncertainty about future risks. In the ROD for the Pristine site EPA defends its rejection of capping by saying " . . . there are no data available on the long term effectiveness and permanence of RCRA caps." Clearly the situation is worse for a simple soil cover.

With regard to groundwater monitoring: "Any increase in existing levels of chromium or lead will be evaluated as to whether corrective action is necessary based on levels found." The ROD did not give any specific technical criteria for deciding when other remedial actions will be necessary.

There was no discussion of the possible future oxidation of trivalent chromium to the more toxic and mobile hexavalent chromium. EPA research has noted: "under conditions prevalent in many soils, Cr(III) can be oxidized." (U.S. Environmental Protection Agency, *Review of In-Place Treatment Techniques for Contaminated Surface Soils*, vol. 2, November 1984.) Such oxidation constitutes a potential mode of failure for the selected remedy, especially in the context of future land use. Although OTA does not know whether the site soil poses this problem, it is an important enough issue to have been examined by EPA. Another potential effect is that trivalent chromium in water can be oxidized to the hexavalent form in certain types of chlorination treatments; therefore, leaching of trivalent chromium into groundwater that eventually enters a drinking water supply can be a problem, especially if it is unexpected.

RIFS contractor.—Camp Dresser and McKee; over $600,000 for all of the RIFS work.

State concurrence.—"The State of Wisconsin supports our preferred alternative, however it has several concerns related to implementation of the remedy. . . . due to the excess cost involved, they do not feel that a groundwater treatment alternative is warranted. The State has concerns over whether adequate cap protection is available for alternatives involving capping the site. . . . the State has agreed to attempt to obtain a voluntary agreement from the landowner."

Community acceptance.—The ROD said the "community does not perceive the site as an immediate danger. . . . at least some residents feel that a full RCRA Subtitle C Cap should be installed."

Special comments.—Although the ROD said the selected soil cover had a low permeability, unlike some other RODs no specific permeability value was given.

Documents obtained from EPA on the use of treatability studies show that a study was completed for the Schmalz site in April and May 1987; the study focused on "surface water contaminated with PCBs, Cr [chromium], and Pb [lead]." This attempt to verify physical and chemical treatment may have been done as part of the earlier operable unit cleanup for PCBs, but the results are relevant to groundwater cleanup for the Schmalz ROD, which does not mention the study.

In the RIFS, the detection limit for hexavalent chromium was 20 times higher than for trivalent chromium, which might explain why hexavalent chromium was not found, if it was present.

Some of the estimated costs for the rejected cleanup alternatives look high. For example, the estimate of $2.8 million for stabilization is higher than estimates at other Superfund sites. With a figure of $200 per cubic yard for total stabilization costs, consistent with data at the Sand Springs and Liquid Disposal sites where stabilization was selected, the correct value for Schmalz is probably about $1.6 million.

The body of the ROD includes a part of the selected remedy that is not in the remedy's description at the beginning of the document. That is the recommendation that "adjacent property be evaluated under the pre-remedial program." Presumably this action refers to the hot spot of contamination just outside the site boundaries used by EPA. Such an examination might, therefore, open up the possibility of another site cleanup, but the ROD only recommended the evaluation instead of requiring it.

General conclusions.—The Schmalz site is definitely *not* one of the worst Superfund sites. But even though the environmental threat from the site is not severe, the handling of the remedial cleanup raises important questions. The degree of certainty expressed by EPA for the long-term effectiveness of its selected remedy is inconsistent with the technical limits of the remedy. A good example of EPA's over optimism is in the responsiveness summary: "Following implementation of the selected remedy, exposure to contamination from the Schmalz Site *will be eliminated*" (emphasis added). This statement is inconsistent with the technical limitations of a soil cover and with uncertain failures, responses to monitoring results, and land use.

Moreover, ROD statements that the "groundwater is not contaminated" are incorrect. The issue is whether the risks estimated by EPA are correct and stable or whether groundwater cleanup is warranted now or whether it may become necessary. EPA seemed to place heavy emphasis on a technicality, namely that contamination within the bureaucratic boundaries of the site was slightly below the current regulatory standard for allowable chromium contamination in drinking water. What if the measured chromium contamination goes up the 5 percent necessary to bring it over the standard? Moreover, the ROD's selected remedy omits the statutory requirement of reexamining the site at least every 5 years because untreated hazardous waste will be left onsite.

The volume of contaminated soil (8,000 cubic yards) at Schmalz is relatively small for a cleanup site. Nevertheless, various ROD statements indicate that minimizing cleanup costs was a significant motivation in the remedy selection. Selecting both soil and groundwater treatment was estimated to cost eight times as much as the soil cover. The ROD said alternative treatment remedies for both contaminated soil and groundwater were rejected because "they are more costly while achieving the same desired results" as the selected remedy. Only by using a narrow, short-term objective of limiting exposure to the hazardous waste are there comparable environmental results of soil treatment and a soil cover.

For the soils problem, the rejection of the solidification/stabilization alternative is inconsistent with generally understood capabilities of the technology. Indeed, having soil contaminated with only two toxic metals, lead and chromium, offers a textbook example of when chemical fixation works best. None of the arguments given in the ROD against using this soil treatment describe especially unique or difficult problems. For example, the presence of large buried objects is faced routinely; they can be washed and reburied. Regarding implementation risks, wetting excavated materials for dust suppression is routine and, in exceptional cases, inflatable domes have been used. The technology has been selected for Superfund sites posing much more challenging kinds and levels of contamination for which solidification is unproven.

The argument that stabilization technology needs to be verified for a site is an argument for conducting a treatability study, preferably during the RIFS, not for rejecting the alternative. If, as the ROD acknowledged to be the case, the soil is contaminated enough to pose a true environmental risk, then the selected remedy of a soil cover is not permanently effective. The absence of land use restrictions is particularly worrisome.

The rejection of groundwater treatment does not consider several factors: 1) values for chromium contamination very close to the MCL; 2) the hot spot of high chromium contamination apparently just outside the site boundary; and 3) the exact environmental and health effects, which might not be eliminated by dilution, resulting from likely continued leaching and migration of contaminants into Lake Winnebago, even if water intrusion is curtailed through the surface of the site. The problem is that groundwater movement will still occur beneath the surface where the contaminated soils reside. At the Liquid Disposal Superfund site in Michigan, a RCRA hazardous waste cap and a containment wall will be built around chemically stabilized material, landfilled onsite, to prevent just this type of leaching and movement of contaminated groundwater.

Moreover, in the Schmalz ROD, no specific criteria were given for groundwater monitoring or for triggering a decision that a groundwater remedy and a better soils remedy are needed. This site highlights a problem found by recent EPA research: "many [Superfund] investigations are not producing sufficient data to adequately characterize ground water conditions near these sites." (R.H. Plumb, Jr., "A Comparision of Ground Water Monitoring Data From CERCLA and RCRA Sites," *Ground Water Monitoring Research*, fall 1987, pp. 94-100.)

Case Study 10
Tacoma Tar Pits, Tacoma, Washington, EPA Region 10

Capsule OTA findings:—No treatability study results supported the selection of chemical stabilization. Significant amounts of untreated contaminants as well as the treated materials will be left onsite. The effectiveness of the treatment is uncertain. Incineration was said to offer no better protection and was rejected because of its higher cost.

Key dates:

- Entered Superfund system: 2/1/82
- Preliminary Assessment: 4/1/82
- Site Inspection: 3/1/83
- National Priorities List
  - —proposed date: 10/81
  - —final date: 9/83
  - —site rank: #347 out of 770
- RIFS start and completion: 11/84 to 9/87
- Public comment period before Record of Decision: 11/6/87 to 12/6/87

- Signing of ROD: 12/30/87
- Estimated complete remediation: Assume 2 years after ROD

Total time.—7 years

Brief description of site.—The site is approximately 30 acres and "within a heavily industrialized area . . . [the] site is part of the Commencement Bay-Nearshore/Tideflats Superfund site located within the Tacoma Tideflats industrial area near Commencement Bay." (The ROD does not describe this action as an operable unit, but that is what it appears to be. However, Tacoma Tar Pits is listed as a separate site in CERCLIS, three years after the large Commencement Bay site entered the system.) "A coal gasification plant was in operation on site from 1924 through 1956. The study area currently contains a metal recycling facility . . . a natural gas transfer station . . . a rail freight loading yard . . . a meat packing plant . . . and a railroad switching yard . . . "

Major contamination/environmental threat.—"The site currently contains two ponds, a small tar pit, and various surface-water drainage ditches. The study area is located near several major surface water bodies [waterways] . . . the Puyallup River, and Commencement Bay. Although none of these water bodies are used for water supply, the bay and river do support extensive fish and shellfish populations. Several portions of Commencement Bay have been identified as being severely contaminated, resulting in adverse biological effects . . . contamination of the local groundwater resource is also of concern. Many local industries use groundwater from on-site wells . . . "

With regard to site contaminants, first found in 1981: "Many of these organic compounds are toxic and several are considered to be carcinogenic. These compounds include aromatic hydrocarbons (i.e., benzene, toluene), polynuclear aromatic hydrocarbons collectively known as PAHs (i.e., napthalene, benzo(a)pyrene), as well as numerous other classes of hydrocarbons and cyanide. Heavy metals . . . include arsenic, mercury, and lead." The automobile recycling facility has also caused lead and PCB contamination. The estimated volume of tar is 5,000 cubic yards; it is mostly in three areas at depths of several feet and more. PCBs are found up to 204 parts per million (ppm), and lead in soil in the 2,000 to 8,000 ppm range. Three shallow aquifers have varying degrees of contamination, and the ROD noted the "current lack of understanding of local groundwater hydrology."

Four indicator compounds were used to estimate risks and establish cleanup goals: benzo(a)pyrene, PCBs, benzene, and lead. For the most part, the cleanup levels are consistent with a 1 in 1 million cancer risk level, except for lead in soil which seems high relative to the MCL value. The major emphasis was correctly put on exposure of onsite workers over short periods.

HRS scores.—groundwater 6.12; surface water 10.91; air 71.92; total 42.20

Removal actions.—None indicated.

Cleanup remedy selected.—This ROD apparently is for an operable unit of the larger Superfund site of which it is a part, even though it did not use the term. Besides the selected remedy, cleanup alternatives examined included containment and landfilling, incineration, in situ vitrification, and groundwater treatment.

"The preferred remedial alternative . . . is a combination of source control measures, measures to control contaminant release, and also measures to reduce human exposure to contaminants. This alternative consists of the excavation of the most severely contaminated soils, stabilization of these soils using a technique which immobilizes contaminants, capping of the stabilized material [with asphalt], treatment of the surface water, continued groundwater monitoring, regulatory controls on water usage for both surface and groundwater, and restrictions on site access." Thoroughly mixed excavated materials will be "fed to a mixing vessel where silicate polymers, cement, and water from the site ponds is added."

However, in site areas that are not severely contaminated with PAHs, soils and sediments "will be excavated to a depth not to exceed 3 feet." This requirement means that significant amounts of contaminants may not be excavated and treated. Exactly what amount will not be excavated cannot be judged from the information given in the ROD, but the site's history and complex contamination suggests that this may be an important limitation to the selected remedy. Many of the contaminants have been present long enough to have migrated downward a significant distance. "The total estimated volume of material to be excavated is 45,000 cubic yards." The total cost for the selected remedy is $3.4 million. This cost implies a rather low cost for the stabilization part of the cleanup of about $50 per cubic yard.

Satisfaction of SARA statutory requirements:

1) Selection of permanent cleanup.—The ROD said: "This remedy satisfies the preference expressed in SARA for treatment that reduces toxicity, mobility, and volume. . . . it is determined that this remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable."

The uncertainty about contaminants left untreated onsite means the selected remedy may not be permanent. The intent to comply with SARA's requirement for 5-year review confirms that the selected remedy is not assuredly permanent. This situation raises questions about future land use. Further uncertainty about permanence is indicated by the ROD's comment: "If as a result of this frequent reassessment, the remedial action is shown to have decreased performance, the nature and extent of additional actions will be considered."

An important issue for Tacoma Tar Pits concerns the cleanup of contaminated groundwater. Although the ROD contained cleanup standards for groundwater, "the remedial action does not currently provide for groundwater extraction and treatment." The basis for this lack of cleanup was that the selected remedy will reduce surface water intrusion and contaminant flow into the water, that existing contamination will be swept away and into its ultimate discharge, and that "Action levels of contaminants in groundwater have not been consistently exceeded at off-site locations." A claim of permanence at this time is premature because the ROD said that it may become necessary to evaluate and implement an alternative remedial action that includes groundwater extraction. A commitment to groundwater monitoring was made, but given the acknowledged complexity of local hydrogeology and given EPA's interest in minimizing cost, it necessitates a major, carefully planned effort.

With regard to the selected stabilization treatment technology: "No bench or pilot studies have been performed to date, these being left until the Remedial Design is commenced . . . " The diverse and highly concentrated contaminants pose a major challenge for a chemical stabilization technology. The current state of knowledge and experience does not support an assumption of effectiveness for the Tacoma Tar Pits site. The ROD noted: "Laboratory experiments will be performed to ensure that the stabilization process effectively immobilizes contaminants. Following this activity, a larger scale 'pilot study' will stabilize a larger volume of contaminated material from the site. This pilot study will determine the effectiveness of the stabilization process." The uncertainty about effectiveness means that the selected remedy did not merit the high (maximum possible) rankings it received for effectiveness in the ROD's analysis of cleanup alternatives. Moreover, there is no basis for saying: "The chemical stabilization process should significantly reduce the toxicity and leachability of site soils." The ability of any chemical stabilization technology to reduce toxicity of a wide range of organic and inorganic contaminants has not been proven nor is it generally accepted in the technical community. But it is reasonable to claim that the mobility of the contaminants might be reduced through stabilization; to claim more than that would require actual test data on site materials. Elsewhere the ROD said: "Permanent treatment can be provided through the immobilization of contaminants." This statement is, however, overly emphatic at the current stage of knowledge about the site.

An important statement on the selected stabilization technology was in the responsiveness summary, given in response to a concern about its effectiveness: "*Although the cement/polymer stabilization process is a proven tech-*

nique for immobilization of heavy metals, this technique has not been conclusively proven to be effective in immobilizing organic contaminants in coal tars. Therefore, both laboratory and bench scale treatability studies will be performed during the design phase of the remedial action to ensure the process will be effective and permanent. . . . the soils/tars containing the highest tar content . . . may be considered for an alternate type of treatment/disposal (i.e., incineration) if the stabilization process is found to be ineffective for the waste matrix" (emphasis added). Also: "Criteria to be used to evaluate the effectiveness of the stabilization process during laboratory and bench scale studies . . . " will be addressed in the design phase.

The FS for the Re-Solve site in Massachusetts rejected stabilization for organic contamination because "there has been limited success in chemically fixing organic contaminants such as solvents and PCBs." The ROD for the Liquid Disposal site in Michigan, which also selected stabilization for soil contaminated with organic chemicals, said that the hazardous substances "will not be permanently destroyed." And the FS for Liquid Disposal said: "Considerable research data exists demonstrating the effectiveness of this technology in immobilizing a wide range of contaminants, primarily inorganics. A substantial amount of data does not exist, however, to accurately judge the long-term reliability of the process."

The ROD for the Tower Chemical Superfund site in Florida said the following about chemical stabilization processes, which it rejected: "This technology would also require long-term (30 years) monitoring which is less favorable than technologies which provide permanent destruction of wastes." The inference is that the technology does not provide permanent destruction of wastes.

Another EPA document, used to teach people about waste treatment said: "Solidification technologies are designed to be used for final waste treatment. This means the technology should be applied only after other treatment techniques have been applied, i.e., incineration, chemical treatment or other." (U.S. Environmental Protection Agency, "RCRA/CERCLA Treatment Alternatives for Hazardous Wastes," October 1987.)

A recent EPA study found "large losses of organics during the mixing process." (L. Weitzman et al., "Evaluation of Solidification/Stabilization As A Best Demonstrated Available Technology," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.) Another EPA study showed that stabilization was not competitive with thermal and chemical treatment technologies and soil washing for organic contamination. (R.C. Thurnau and M.P. Esposito, "TCLP As A Measure of Treatment Effectiveness: Results of TCLP Work Completed on Different Treatment Technologies for CERCLA Soils," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.) A demonstration of a stabilization technology under EPA auspices concluded that "for the organics, the leachate concentrations were approximately equal for the treated and untreated soils." (P.R. de Percin and S. Sawyer, "SITE Demonstration of Hazcon Solidification/Stabilization Process," paper presented at EPA's *Fourteenth Annual Research Symposium*, May 1988.)

The rejection of other treatment technologies for Tacoma Tar Pits did not have much technical analysis behind it. The analysis in the ROD rests mainly on a very simple rating system. For example, all 10 alternatives, including capping the waste and incinerating it, received the same rating of high for technical feasibility (including effectiveness, useful life, operation and maintenance requirements, possible failure modes, constructability, implementation time, worker safety, and neighborhood safety). All but the two no action or nearly no action options received the same high rating for public health impacts (including minimization of chemical releases, exposures during remedial action, and exposures after remedial action). But sound technical bases exist for finer distinctions among such a broad range of alternatives. For example, the incineration options offered substantially greater effectiveness, reliability, permanency, and certainty of destruction of toxic substances than capping the waste or the selected remedy.

The estimated costs of the alternatives probably weighed heavily: two incineration options (including stabilization of residue) had total costs of $17 million (only surface soils) and $243 million (all soil with contamination with a risk greater than 1 in 1 million cancer risk); both options included groundwater pumping and treatment. In comparison, the selected remedy (stabilization) would cost $8 million if groundwater treatment is included in the calculation. The cost will be only $3.4 million, however, because groundwater treatment was excluded.

2) Accurate assessment of land disposal and containment alternatives.—There is a statement on future land use: "Land use restrictions will be imposed to prevent or require stringent control of future excavation on the site, to prevent future use of surface water and shallow groundwater, and to prevent site access by personnel other than site workers." However, there is no detailed analysis of possible future failures of the landfill in which the contaminated materials will be re-buried after stabilization.

The ROD for the Tower Chemical site made a good point about concrete or asphalt caps (as selected for Tacoma Tar Pits): "The risk of failure . . . is high due to the potential for fracture formation." The FS for the Pristine site says: "Asphalt is photosensitive, and subject to cracking due to settling, chemical action, and vegetation. Frequent inspections are required to ensure cap integrity." The asphalt cap option was rejected at both of these sites.

RIFS contractor.—The studies were paid for by responsible parties. The ROD noted that, although EPA and the State found the documents acceptable, "EPA has prepared an addendum for each document addressing issues that the studies have inadequately or incompletely addressed." Geotechnology, Inc., performed the RI; Envirosphere Company (Ebasco) performed the FS. For the entire Commencement Bay/Nearshor/Tideflats site, the SCAP indicates three different RIFSs with the last one labeled Tar Pits started on 9/23/83 and then taken over by the PRPs on 11/1/84. It is not clear what actions resulted from the two earlier RIFSs and no completion dates for them are indicated; $2.5 million was spent by the government on the first one in 1982 and 1983.

State concurrence.—"The State of Washington has been consulted and has verbally concurred with the selected remedy." Verbal concurrence may indicate a rushed ROD at the end of the fiscal year quarter.

Community acceptance.—The ROD noted that community interest "has not been actively demonstrated." The reasons given for the lack of community interest are the site's location within the larger Commencement Bay Superfund site, the lack of private residences nearby, and a number of cleanup actions already taken in the area.

Special comments.—Although there are statements about restricting future land use, there are also statements that suggest that those restrictions may be applied only in the short term. For example: "The [stabilization] reagent composition is formulated to provide a high-strength surface capable of supporting trucks and other vehicles."

Cleanup goals were set for indicator contaminants. While these goals make risk assessment more manageable, there can be problems with using them for analysis of the effectiveness of a cleanup technology that is chemical specific, such as chemical stabilization. Moreover, the cleanup very much depends on data that reveal areas of high tar concentration, where there is no excavation depth limit. However, there may be other areas that have high concentrations of other contaminants and that may be either overlooked or fall under the provision of the excavation depth limit. Compounding the problem is the relatively small amount of soil sampling that has been reported, averaging only about 1.5 locations per acre.

The administrative record indicated a large number of contractors have performed studies on the site. It is not clear whether EPA had independent work done to verify work done for the responsible parties. There is also some confusion about the relationship between Tacoma

Tar Pits and the larger Commencement Bay site because the former is listed separately in CERCLIS and the ROD does not use the term operable unit.

General conclusions.—The technical information obtained prior to and used in the ROD did not support claims that the selected remedy is permanent nor even that it will be effective. Delaying testing of the chosen stabilization technology and setting of criteria for its effectiveness until after the ROD undercuts the claim that a permanent remedy has already been selected. The scope and depth of analysis of alternative cleanup technologies was less than seen in any other ROD examined in this report. This shortcoming directly affected technology selection; it may be related to the strong involvement of the responsible parties, particularly in conducting the RIFS. (An experienced attorney advises responsible parties: "Participation in the [RIFS] study provides an opportunity to generate information that can sway EPA decision makers on important issues. We all know that one can interpret the same data a number of ways. Differing conclusions can be made and supported from the same data. A company that uses its experts to argue convincingly in favor of one conclusion often can influence the ultimate decision." [P. H. Haller, *Hazardous Materials*, January-February 1988.])

While the ROD's interest in alternative treatment technology is commendable, the chief driving force for selecting the remedy appears to be cost: "The final selected remedy meets the requirement of cost-effectiveness as this alternative provides for permanent treatment, and contaminant release minimization for a cost significantly less than other alternatives exhibiting a similar level of protection. Additional cost of these [other alternatives] is the result of the use of more costly technologies such as incineration . . . or the excavation of larger volumes of soils coupled with off-site landfilling." But no data support the contention of similar or equal levels of protection for stabilization and incineration; therefore, the claim that the selected remedy is cost-effective is unsupported.

However, incineration for a comparable volume of contaminated soil definitely would be much more expensive ($242 million) and, therefore, this site, like many others, shows how important it is to examine the issue of comparable environmental protection for a cost-effectiveness decision. Moreover, Tacoma Tar Pits illustrates the need to consider a broader range of treatment technologies to reduce cleanup costs. Biological treatment for such a site deserves attention. The case for its consideration at Tacoma Tar Pits, for example, was as good, if not better, than for the Renora site where it was chosen without treatability test data to support the decision. A research program on developing biotechnology for cleaning up old manufactured gas plant sites such as Tacoma Tar Pits is underway at the University of Tennessee with support from the Gas Research Institute. The choice at Tacoma Tar Pits could have included postponing the remedial action or conducting treatability studies for biological treatment.

Moreover, the cost of the selected remedy may have been significantly under estimated. Data from a vendor of the stabilization technology most likely to be effective on this site suggests a cost of about $150 per cubic yard instead of the $50 indicated in the ROD. If major costs for treatability studies are added in, the cost of the selected remedy could be about $5 million more than the $3.4 million estimated in the ROD for a total of $8.4 million. The higher cost matches the low range of the ROD's incineration options without groundwater treatment.

The lack of a commitment to groundwater cleanup may be linked to the location of the site in a highly contaminated area, including contaminated major water bodies. This is a situation where analyzing the cleanup in isolation may be misleading and ultimately inefficient.

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